SR 710 North Study

Groundborne Noise and Vibration Impacts

Prepared for

Caltrans
CALIFORNIA DEPARTMENT OF TRANSPORTATION

Metro
Los Angeles County
Metropolitan Transportation Authority

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Acronyms and Abbreviations

AF – adjustment factor

BVR – building vibration response

dB – decibel

dBA – A-weighted decibels

FDL – force density level

FTA – Federal Transit Administration

Hz – hertz (cycles per second)

IL – insertion loss

LRT – light rail transit

LRV – light rail vehicle

LSR – line source response

Pa – Pascals (unit of pressure)

rms – root mean square

SPL – sound pressure level

VdB – vibration decibels

Project Description

1.1 Introduction

The California Department of Transportation (Caltrans), in cooperation with the Los Angeles County Metropolitan Transportation Authority (Metro) proposes transportation improvements to improve mobility and relieve congestion in the area between State Route 2 (SR 2) and Interstates 5, 10, 210 and 605 (I-5, I-10, I-210, and I-605, respectively) in east/northeast Los Angeles and the western San Gabriel Valley. The study area for the State Route 710 (SR 710) North Study as depicted on Figure 1-1 is approximately 100 square miles and generally bounded by I-210 on the north, I-605 on the east, I-10 on the south, and I-5 and SR 2 on the west. Caltrans is the Lead Agency under the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

1.2 Purpose and Need

1.2.1 Purpose of the Project

Due to the lack of continuous north-south transportation facilities in the study area, there is congestion on freeways, cut-through traffic that affects local streets, and low-frequency transit operations in the study area. Therefore, the following project purpose has been established.

The purpose of the proposed action is to effectively and efficiently accommodate regional and local north-south travel demands in the study area of the western San Gabriel Valley and east/northeast Los Angeles, including the following considerations:

- Improve efficiency of the existing regional freeway and transit networks.
- Reduce congestion on local arterials adversely affected due to accommodating regional traffic volumes.
- Minimize environmental impacts related to mobile sources.

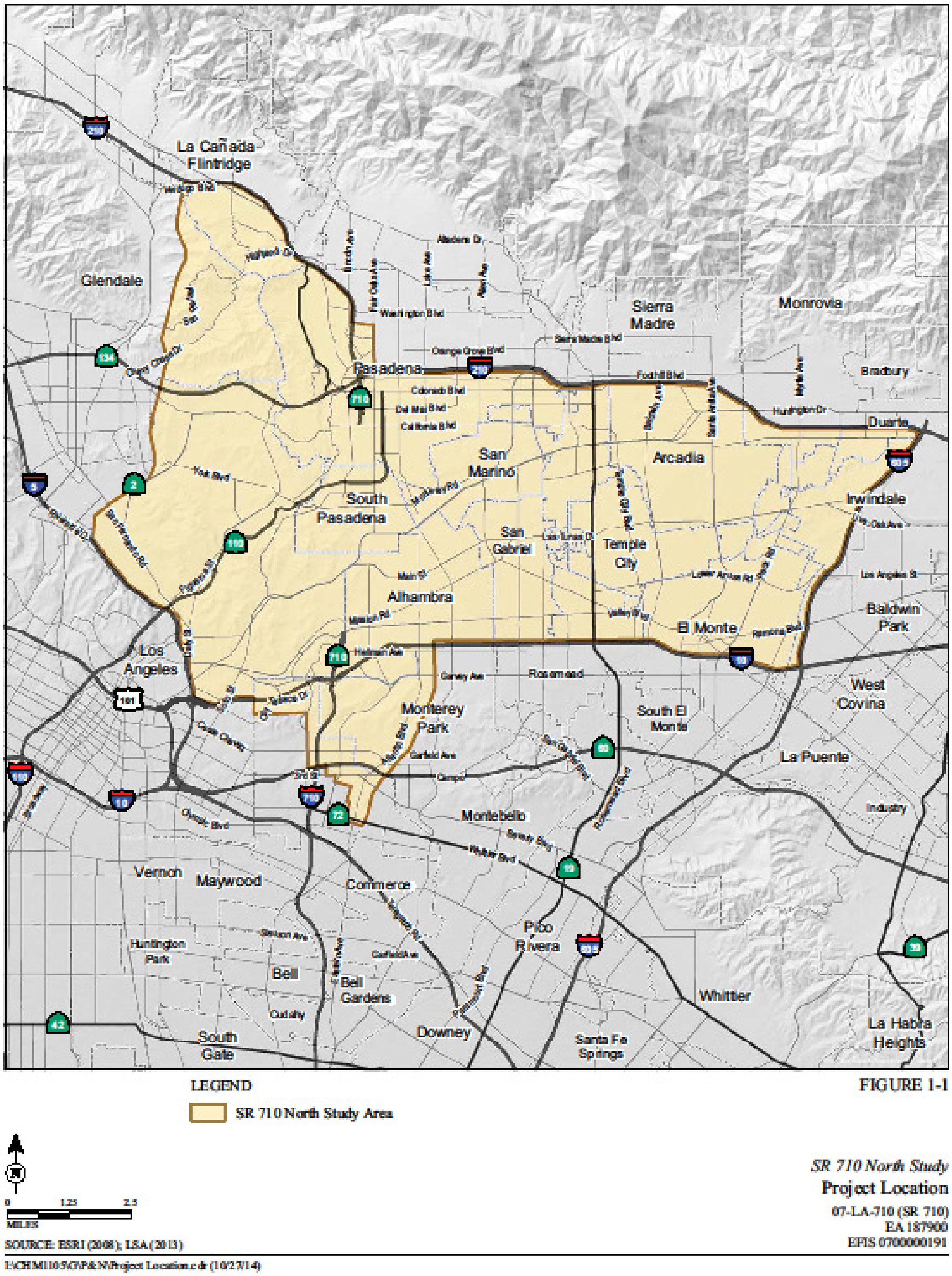
1.2.2 Need for the Project

The study area is centrally located within the extended urbanized area of Southern California. With few exceptions, the area from Santa Clarita in the north to San Clemente in the south (a distance of approximately 90 miles [mi]) is continuously urbanized. Physical features such as the San Gabriel Mountains and Angeles National Forest on the north, and the Puente Hills and Cleveland National Forest on the south, have concentrated urban activity between the Pacific Ocean and these physical constraints. This urbanized area functions as a single social and economic region that is identified by the Census Bureau as the Los Angeles-Long Beach-Santa Ana Metropolitan Statistical Area (MSA).

There are seven major east-west freeway routes:

- State Route 118 (SR 118)
- United States Route 101 (US-101)/State Route 134 (SR 134)/I-210
- I-10
- State Route 60 (SR 60)

Figure 1-1: SR 710 Study Area



- Interstate 105 (I-105)
- State Route 91 (SR 91)
- State Route 22 (SR 22)

There are seven major north-south freeway routes:

- Interstate 405 (I-405)
- US-101/State Route 170 (SR 170)
- I-5
- Interstate 110 (I-110)/State Route 110 (SR 110)
- Interstate 710 (I-710)
- I-605
- State Route 57 (SR 57)

All of these major routes are located in the central portion of the Los Angeles-Long Beach-Santa Ana MSA. Of the seven north-south routes, four are located partially within the study area (I-5, I-110/SR 110, I-710, and I-605), two of which (I-110/SR 110 and I-710) terminate within the study area without connecting to another freeway. As a result, a substantial amount of north-south regional travel demand is concentrated on a few freeways, or diverted to local streets within the study area. This effect is exacerbated by the overall southwest-to-northeast orientation of I-605, which makes it an unappealing route for traffic between the southern part of the region and the urbanized areas to the northwest in the San Fernando Valley, the Santa Clarita Valley, and the Arroyo-Verdugo region.

The lack of continuous north-south transportation facilities in the study area has the following consequences, which have been identified as the elements of need for the project:

- Degradation of the overall efficiency of the larger regional transportation system
- Congestion on freeways in the study area
- Congestion on the local streets in the study area
- Poor transit operations within the study area

1.3 Alternatives

The proposed alternatives include the No Build Alternative, the Transportation System Management/ Transportation Demand Management (TSM/TDM) Alternative, the Bus Rapid Transit (BRT) Alternative, the Light Rail Transit (LRT) Alternative, and the Freeway Tunnel Alternative. These alternatives are each discussed below.

1.3.1 No Build Alternative

The No Build Alternative includes projects/planned improvements through 2035 that are contained in the Federal Transportation Improvement Program (FTIP), as listed in the Southern California Association of Governments (SCAG) 2012 Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) Measure R and the funded portion of Metro’s 2009 Long Range Transportation Plan (LRTP). The No Build Alternative does not include any planned improvements to the SR 710 Corridor. Figure 1-2 illustrates the projects in the No Build Alternative.

1.3.2 Transportation System Management/Transportation Demand Management (TSM/TDM) Alternative

The TSM/TDM Alternative consists of strategies and improvements to increase efficiency and capacity for all modes in the transportation system with lower capital cost investments and/or lower potential impacts. The TSM/TDM Alternative is designed to maximize the efficiency of the existing transportation system by improving capacity and reducing the effects of bottlenecks and chokepoints. Components of the TSM/TDM Alternative are shown on Figure 1-3. TSM strategies increase the efficiency of existing facilities (i.e., TSM strategies are actions that increase the number of vehicle trips which a facility can carry without increasing the number of through lanes).

1.3.2.1 Transportation System Management

TSM strategies include Intelligent Transportation Systems (ITS), local street and intersection improvements, and Active Traffic Management (ATM):

- **ITS Improvements:** ITS improvements include traffic signal upgrades, synchronization and transit prioritization, arterial changeable message signs (CMS), and arterial video and speed data collection systems. The TSM/TDM Alternative includes signal optimization on corridors with signal coordination hardware already installed by Metro's Traffic Signal Synchronization Program (TSSP). These corridors include Del Mar Avenue, Rosemead Boulevard, Temple City Boulevard, Santa Anita Avenue, Fair Oaks Avenue, Fremont Avenue, and Peck Road. The only remaining major north-south corridor in the San Gabriel Valley in which TSSP has not been implemented is Garfield Avenue; therefore, TSSP on this corridor is included in the TSM/TDM Alternative. The locations are shown in Table 1.1. The following provide a further explanation of the ITS elements listed above:
  - Traffic signal upgrades include turn arrows, vehicle and/or bicycle detection, pedestrian countdown timers, incorporation into regional management traffic center for real-time monitoring of traffic and updating of signal timing.
  - Synchronization is accomplished through signal coordination to optimize travel times and reduce delay.
  - Transit signal prioritization includes adjusting signal times for transit vehicles to optimize travel times for public transit riders.
  - Arterial CMS are used to alert travelers about unusual road conditions, special event traffic, accident detours, and other incidents.
  - Video and speed data collection includes cameras and other vehicle detection systems that are connected to a central monitoring location, allowing for faster detection and response to traffic incidents and other unusual traffic conditions.
- **Local Street and Intersection Improvements:** The local street and intersection improvements are within the Cities of Los Angeles, Pasadena, South Pasadena, Alhambra, San Gabriel, Rosemead, and San Marino. Table 1.2 outlines the location of the proposed improvements to local streets, intersections, and freeway ramps as well as two new local roadways.

Figure 1-2: No Build Alternative

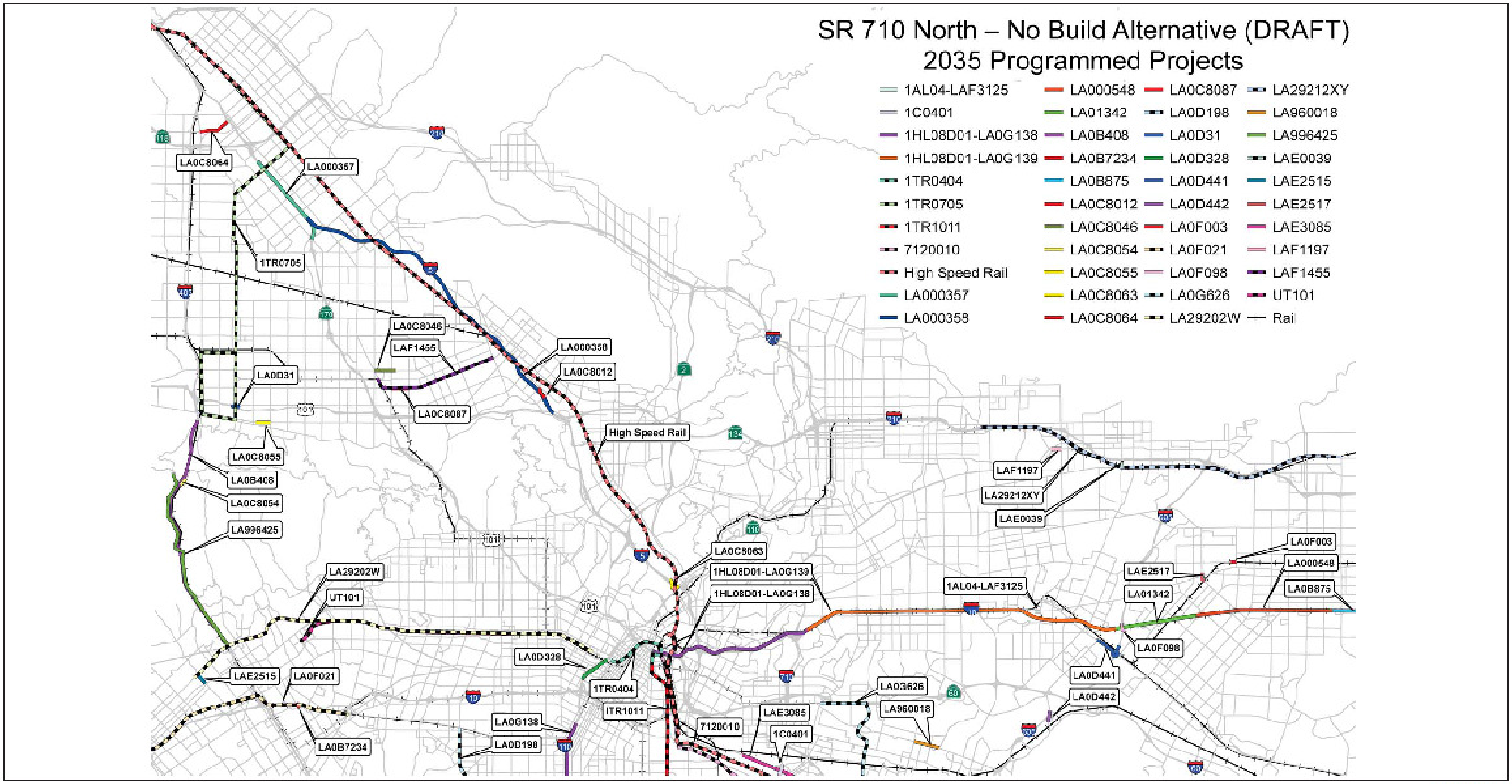


FIGURE 1-2

NOT TO SCALE

SOURCE: CH2M HILL (2013)

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SR 710 North Study

No Build Alternative

07-LA-710 (SR 710)
EA 187900
EFIS 0700000191

Figure 1-3: TSM/TDM Alternative

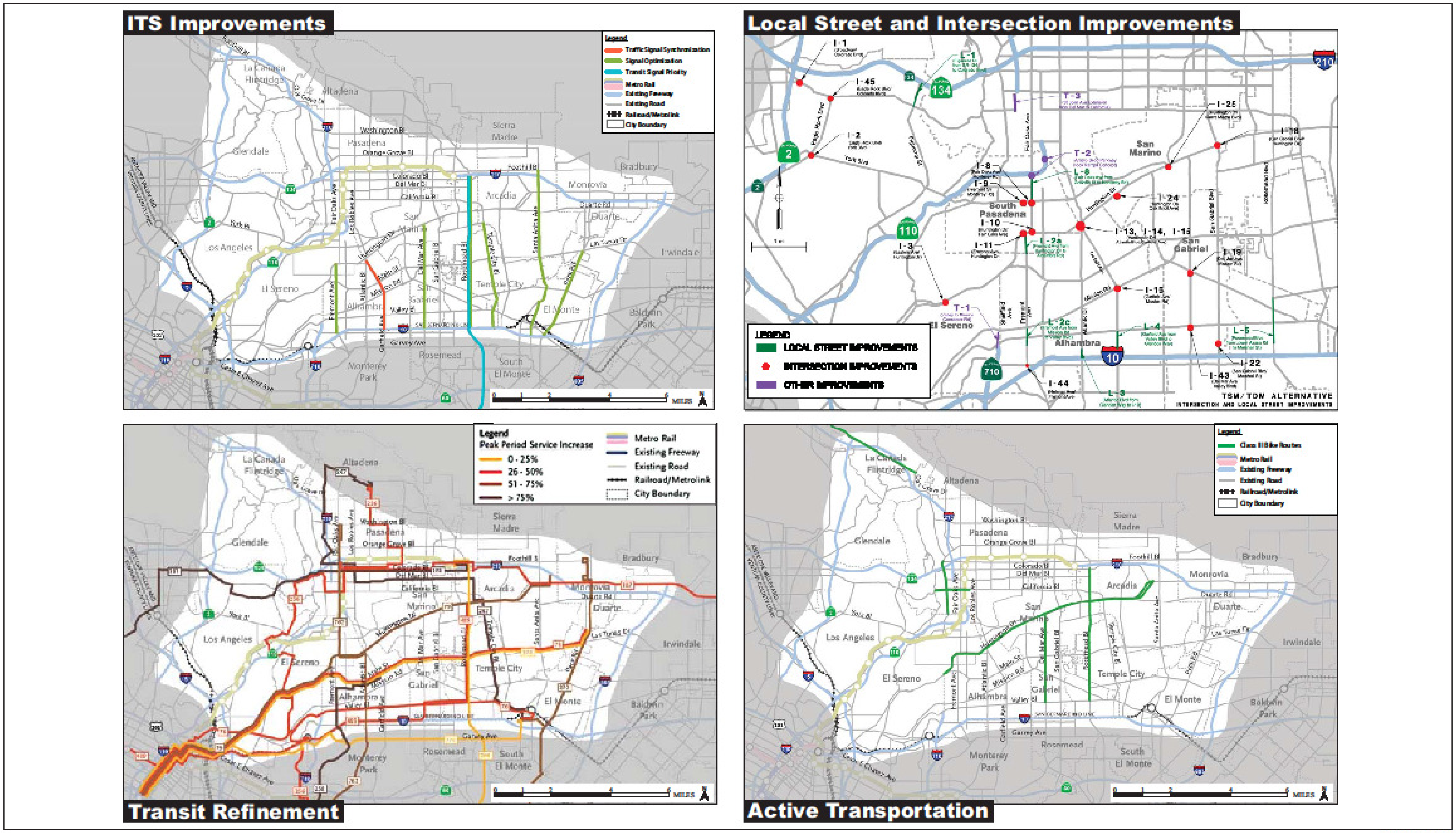

FIGURE 1-3

SR 710 North Study
TSM/TDM Alternative
07-LA-710 (SR 710)
EA 18 7900
EFIS 0700000191

SOURCE: CH2M HILL (2013)
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TABLE 1.1:
TSM/TDM Alternative Elements

ID No.	Description	Location
	ITS Improvements	
ITS-1	Transit Signal Priority	Rosemead Boulevard (from Foothill Boulevard to Del Amo Boulevard)
ITS-2	Install Video Detection System on SR 110	SR 110 north of US-101
ITS-3	Install Video Detection System at Intersections	At key locations in study area
ITS-4	Arterial Speed Data Collection	On key north/south arterials
ITS-5	Install Arterial CMS	At key locations in study area
ITS-6	Traffic Signal Synchronization on Garfield Avenue	Huntington Drive to I-10
ITS-7	Signal optimization on Del Mar Avenue	Huntington Drive to I-10
ITS-8	Signal optimization on Rosemead Boulevard	Foothill Boulevard to I-10
ITS-9	Signal optimization on Temple City Boulevard	Duarte Road to I-10
ITS-10	Signal optimization on Santa Anita Avenue	Foothill Boulevard to I-10
ITS-11	Signal optimization on Peck Road	Live Oak Avenue to I-10
ITS-12	Signal optimization on Fremont Avenue	Huntington Drive to I-10

CMS = changeable message signs
I-10 = Interstate 10
ITS = Intelligent Transportation Systems
SR 110 = State Route 110
TDM = Transportation Demand Management
TSM = Transportation System Management
US-101 = United States Route 101

TABLE 1.2:
Local Street and Intersection Improvements of the TSM/TDM Alternative

ID No.	Description	Location
	Local Street Improvements	
L-1	Figueroa Street from SR 134 to Colorado Boulevard	City of Los Angeles (Eagle Rock)
L-2a	Fremont Avenue from Huntington Drive to Alhambra Road	City of South Pasadena
L-2c	Fremont Avenue from Mission Road to Valley Boulevard	City of Alhambra
L-3	Atlantic Boulevard from Glendon Way to I-10	City of Alhambra
L-4	Garfield Avenue from Valley Boulevard to Glendon Way	City of Alhambra
L-5	Rosemead Boulevard from Lower Azusa Road to Marshall Street	City of Rosemead
L-8	Fair Oaks Avenue from Grevelia Street to Monterey Road	City of South Pasadena
	Intersection Improvements	
I-1	West Broadway/Colorado Boulevard	City of Los Angeles (Eagle Rock)
I-2	Eagle Rock Boulevard/York Boulevard	City of Los Angeles (Eagle Rock)
I-3	Eastern Avenue/Huntington Drive	City of Los Angeles (El Sereno)
I-8	Fair Oaks Avenue/Monterey Road	City of South Pasadena
I-9	Fremont Street/Monterey Road	City of South Pasadena
I-10	Huntington Drive/Fair Oaks Avenue	City of South Pasadena
I-11	Fremont Avenue/Huntington Drive	City of South Pasadena
I-13	Huntington Drive/Garfield Avenue	Cities of Alhambra/South Pasadena/San Marino
I-14	Huntington Drive/Atlantic Boulevard	Cities of Alhambra/South Pasadena/San Marino
I-15	Atlantic Boulevard/Garfield Avenue	Cities of Alhambra/South Pasadena/San Marino
I-16	Garfield Avenue/Mission Road	City of Alhambra
I-18	San Gabriel Boulevard/Huntington Drive	City of San Marino/Unincorporated Los Angeles County (East Pasadena/East San Gabriel)
I-19	Del Mar Avenue/Mission Road	City of San Gabriel
I-22	San Gabriel Boulevard/Marshall Street	City of San Gabriel
I-24	Huntington Drive/Oak Knoll Avenue	City of San Marino
I-25	Huntington Drive/San Marino Avenue	City of San Marino
I-43	Del Mar Avenue/Valley Boulevard	City of San Gabriel
I-44	Hellman Avenue/Fremont Avenue	City of Alhambra
I-45	Eagle Rock Boulevard/Colorado Boulevard	City of Los Angeles (Eagle Rock)
	Other Road Improvements	
T-1	Valley Boulevard to Mission Road Connector Road	Cities of Alhambra/Los Angeles (El Sereno)
T-2	SR 110/Fair Oaks Avenue Hook Ramps	Cities of South Pasadena/Pasadena
T-3	St. John Avenue Extension between Del Mar Boulevard and California Boulevard	City of Pasadena

I-10 = Interstate 10
I-710 = Interstate 710
NB = northbound
SB = southbound
SR 110 = State Route 110
SR 134 = State Route 134
TDM = Transportation Demand Management
TSM = Transportation System Management

- **Active Traffic Management:** ATM technology and strategies are also included in the TSM/TDM Alternative. The major elements of ATM are arterial speed data collection and CMS. Data on arterial speeds would be collected and distributed through Los Angeles County's Information Exchange Network (IEN). Many technologies are available for speed data collection or the data could be purchased from a third-party provider. Travel time data collected through this effort could be provided to navigation system providers for distribution to the traveling public. In addition, arterial CMS or "trailblazer" message signs would be installed at key locations to make travel time and other traffic data available to the public.

1.3.2.2 Transportation Demand Management

TDM strategies focus on regional means of reducing the number of vehicle trips and vehicle miles traveled as well as increasing vehicle occupancy. TDM strategies facilitate higher vehicle occupancy or reduce traffic congestion by expanding the traveler's transportation options in terms of travel method, travel time, travel route, travel costs, and the quality and convenience of the travel experience. The TDM strategies include reducing the demand for travel during peak periods, reducing the use of motor vehicles, shifting the use of motor vehicles to uncongested times of the day, encouraging rideshare and transit use, eliminating trips (i.e., telecommuting), and improved transportation options. The TDM strategies include expanded bus service, bus service improvements, and bicycle improvements:

- **Expanded Bus Service and Bus Service Improvements:** Transit service improvements included in the TSM/TDM Alternative are summarized in Tables 1.3 and 1.4 and illustrated on Figure 1-3. The transit service improvements enhance bus headways between 10 and 30 minutes during the peak hour and 15 to 60 minutes during the off-peak period. Bus headways are the amount of time between consecutive bus trips (traveling in the same direction) on the bus route. Some of the bus service enhancements almost double existing bus service.
- **Bicycle Facility Improvements:** The bicycle facility improvements include on-street Class III bicycle facilities that support access to transit facilities through the study area and expansion of bicycle parking facilities at existing Metro Gold Line stations. Proposed bicycle facility improvements are outlined in Table 1.4.

1.3.3 Bus Rapid Transit (BRT) Alternative

The BRT Alternative would provide high-speed, high-frequency bus service through a combination of new, dedicated, and existing bus lanes, and mixed-flow traffic lanes to key destinations between East Los Angeles and Pasadena. The proposed route length is approximately 12 mi. Figure 1-4 illustrates the BRT Alternative.

The BRT Alternative includes the BRT trunk line arterial street and station improvements, frequent bus service, new bus feeder services, and enhanced connecting bus services. BRT includes bus enhancements identified in the TSM/TDM Alternative, except for improvements to Route 762.

Buses are expected to operate every 10 minutes during peak hours and every 20 minutes during off-peak hours. The BRT service would generally replace, within the study area, the existing Metro Route 762 service. The 12 mi route would begin at Atlantic Boulevard and Whittier Boulevard to the south, follow Atlantic Boulevard, Huntington Drive, Fair Oaks Avenue, Del Mar Boulevard, and end with a terminal loop in Pasadena to the north. Buses operating in the corridor would be given transit signal priority from a baseline transit signal priority project that will be implemented separately by Metro.

Figure 1-4: BRT Alternative

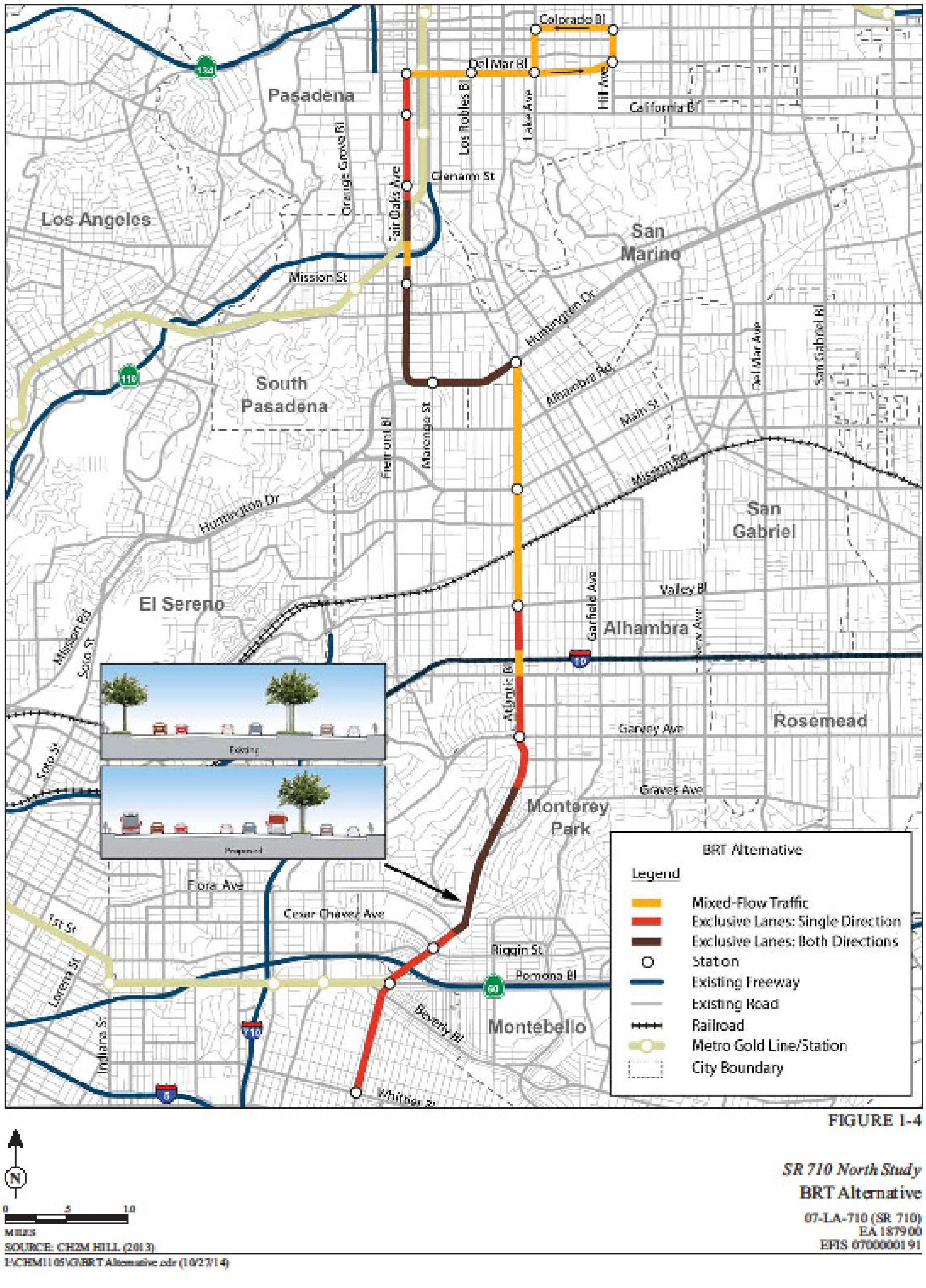


TABLE 1.3:
Transit Refinements of the TSM/TDM Alternative

Bus Route	Operator	Route Type	Route Description	Existing Headways		Enhanced Headways	
				Peak	Off-Peak	Peak	Off-Peak
70	Metro	Local	From Downtown Los Angeles to El Monte via Garvey Avenue	10-12	15	10	15
770	Metro	Rapid	From Downtown Los Angeles to El Monte via Garvey Avenue/Cesar Chavez Avenue	10-13	15	10	15
76	Metro	Local	From Downtown Los Angeles to El Monte via Valley Boulevard	12-15	16	10	15
78	Metro	Local	From Downtown Los Angeles to Irwindale via Las Tunas Drive	10-20	16-40	10	15
378	Metro	Limited	From Downtown Los Angeles to Irwindale via Las Tunas Drive	18-23	-	20	30
79	Metro	Local	From Downtown Los Angeles to Santa Anita via Huntington Drive	20-30	40-45	15	30
180	Metro	Local	From Hollywood to Altadena via Los Feliz/Colorado Boulevard	30	30-32	15	30
181	Metro	Local	From Hollywood to Pasadena via Los Feliz/Colorado Boulevard	30	30-32	15	30
256	Metro	Local	From Commerce to Altadena via Hill Avenue/Avenue 64/Eastern Avenue	45	45	30	40
258	Metro	Local	From Paramount to Alhambra via Fremont Avenue/ Eastern Avenue	48	45-55	20	30
260	Metro	Local	From Compton to Altadena via Fair Oaks Avenue/ Atlantic Boulevard	16-20	24-60	15	30
762[1]	Metro	Rapid	From Compton to Altadena via Atlantic Boulevard	25	30-60	15	30
266	Metro	Local	From Lakewood to Pasadena via Rosemead Boulevard/Lakewood Boulevard	30-35	40-45	15	30
267	Metro	Local	From El Monte to Pasadena via Temple City Boulevard/Del Mar Boulevard	30	30	15	30
485	Metro	Express	From Union Station to Altadena via Fremont/Lake Avenue	40	60	30	60
487	Metro	Express	From Westlake to El Monte via Santa Anita Avenue/ Sierra Madre Boulevard/San Gabriel Boulevard	18-30	45	15	30
489	Metro	Express	From Westlake to East San Gabriel via Rosemead Boulevard	18-20	-	15	-
270	Metro	Local	From Norwalk to Monrovia via Workman Mill/Peck Road	40-60	60	30	60
780	Metro	Rapid	From West LA to Pasadena via Fairfax Avenue/ Hollywood Boulevard/Colorado Boulevard	10-15	22-25	10	20
187	Foothill	Local	From Pasadena to Montclair via Colorado Boulevard/ Huntington Drive/Foothill Boulevard	20	20	15	15

[1] This route would not be included as part of the BRT Alternative because the BRT Alternative would replace this service.

BRT = Bus Rapid Transit
Express = Express Bus
Foothill = Foothill Transit
Metro = Los Angeles County Metropolitan Transportation Authority
Rapid = Bus Rapid Transit
TDM = Transportation Demand Management
TSM = Transportation System Management

TABLE 1.4:
Active Transportation and Bus Enhancements of the TSM/TDM Alternative

ID No.	Description	Location
Bus Service Improvements		
Bus-1	Additional bus service	See Table 1.3 and Figure 1-3
Bus-2	Bus stop enhancements	Along routes listed in Table 1.3
Bicycle Facility Improvements		
Bike-1	Rosemead Boulevard bike route (Class III)	Colorado Boulevard to Valley Boulevard (through Los Angeles County, Temple City, Rosemead)
Bike-2	Del Mar Avenue bike route (Class III)	Huntington Drive to Valley Boulevard (through San Marino, San Gabriel)
Bike-3	Huntington Drive bike route (Class III)	Mission Road to Santa Anita Avenue (through the City of Los Angeles, South Pasadena, San Marino, Alhambra, Los Angeles County, Arcadia)
Bike-4	Foothill Boulevard bike route (Class III)	In La Cañada Flintridge
Bike-5	Orange Grove bike route (Class III)	Walnut Street to Columbia Street (in Pasadena)
Bike-6	California Boulevard bike route (Class III)	Grand Avenue to Marengo Avenue (in Pasadena)
Bike-7	Add bike parking at transit stations	Metro Gold Line stations
Bike-8	Improve bicycle detection at existing intersections	Along bike routes in study area

Metro = Los Angeles County Metropolitan Transportation Authority
TDM = Transportation Demand Management
TSM = Transportation System Management

Where feasible, buses would run in dedicated bus lanes adjacent to the curb, either in one direction or both directions, during peak periods. The new dedicated bus lanes would generally be created within the existing street rights of way (ROW) through a variety of methods that include restriping the roadway, restricted on-street parking during peak periods, narrowing medians, planted parkways, or sidewalks. Buses would share existing lanes with other traffic in cases where there is not enough ROW. The exclusive lanes would be exclusive to buses and right-turning traffic during a.m. and p.m. peak hours only. At other times of day, the exclusive lanes would be available for on-street parking use.

A total of 17 BRT stations with amenities would be placed on average, at approximately 0.8 mi intervals at major activity centers and cross streets. Typical station amenities would include new shelters, branding elements, seating, wind screens, leaning rails, variable message signs (next bus information), lighting, bus waiting signals, trash receptacles, and stop markers. Some of these stops will be combined with existing stops, while in some cases, new stops for BRT will be provided. The BRT service would include 60-foot (ft) articulated buses with three doors, and would have the latest fare collection technology such as on-board smart card (Transit Access Pass [TAP] card) readers to reduce dwell times at stations. The BRT stops would be provided at the following 17 locations:

- Atlantic Boulevard at Whittier Boulevard
- Atlantic Boulevard between Pomona Boulevard and Beverly Boulevard
- Atlantic Boulevard at Cesar Chavez Avenue/Riggin Street
- Atlantic Boulevard at Garvey Avenue
- Atlantic Boulevard at Valley Boulevard
- Atlantic Boulevard at Main Street
- Huntington Drive at Garfield Avenue
- Huntington Drive at Marengo Avenue
- Fair Oaks Avenue at Mission Street
- Fair Oaks Avenue at Glenarm Street

- Fair Oaks Avenue at California Boulevard
- Fair Oaks Avenue at Del Mar Boulevard
- Del Mar Boulevard at Los Robles Avenue
- Del Mar Boulevard at Lake Avenue
- Del Mar Boulevard at Hill Avenue (single direction only)
- Colorado Boulevard at Hill Avenue (single direction only)
- Colorado Boulevard at Lake Avenue (single direction only)

Additionally, this alternative would include bus feeder routes that would connect additional destinations with the BRT mainline. Two bus feeder routes are proposed: one that would run along Colorado Boulevard, Rosemead Boulevard, and Valley Boulevard to the El Monte transit station; and another bus feeder route that would travel from Atlantic Boulevard near the Gold Line station to the Metrolink stations in the City of Commerce and Montebello via Beverly Boulevard and Garfield Avenue. In addition, other existing bus services in the study area would be increased in frequency and/or span of service. The El Sol shuttle improvements are an existing bus service that would be increased in frequency. The headways on the El Sol shuttle “City Terrace/East Los Angeles College (ELAC)” route that connect ELAC to the proposed Floral Station would be reduced from 60 minutes to 15 minutes.

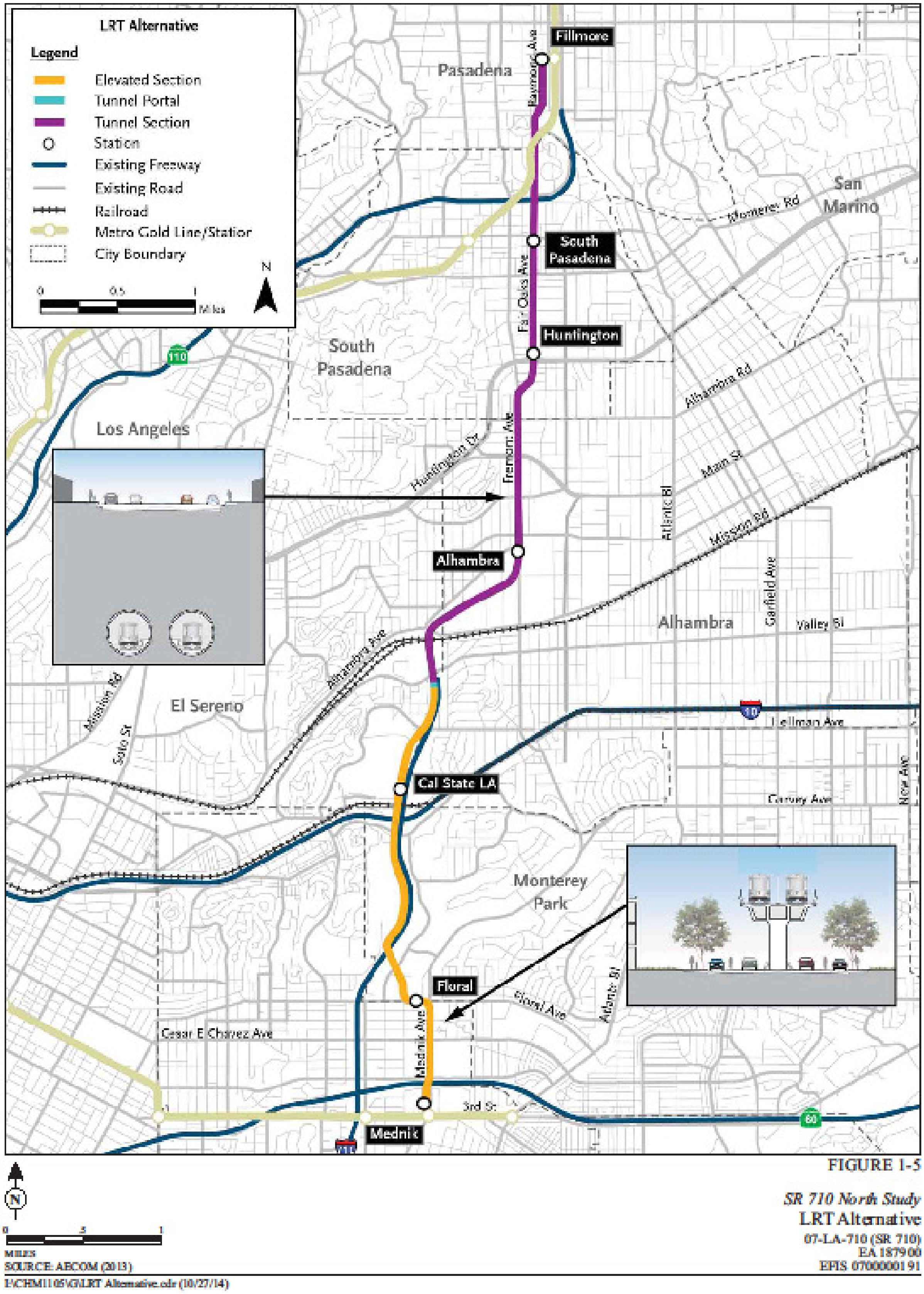
The TSM/TDM Alternative improvements would also be constructed as part of the BRT Alternative, except as noted below. These improvements would provide the additional enhancements to maximize the efficiency of the existing transportation system by improving capacity and reducing the effects of bottlenecks and chokepoints. Local Street Improvements L-8 (Fair Oaks Avenue from Grevelia Street to Monterey Road) and the reversible lane component of L-3 (Atlantic Boulevard from Glendon Way to I-10) would not be constructed with the BRT Alternative.

1.3.4 Light Rail Transit (LRT) Alternative

The LRT Alternative would include passenger rail operated along a dedicated guideway, similar to other Metro light rail lines. The LRT alignment is approximately 7.5 mi long, with 3 mi of aerial segments and 4.5 mi of bored tunnel segments. Figure 1-5 illustrates the LRT Alternative.

The LRT Alternative would begin at an aerial station on Mednik Avenue adjacent to the existing East Los Angeles Civic Center Station on the Metro Gold Line. The alignment would remain elevated as it travels north on Mednik Avenue, west on Floral Drive, north across Corporate Center Drive, and then along the west side of I-710, primarily in Caltrans ROW, to a station adjacent to the California State University, Los Angeles (Cal State LA). The alignment would descend into a tunnel south of Valley Boulevard and travel northeast to Fremont Avenue, north under Fremont Avenue, and easterly to Fair Oaks Avenue. The alignment would then cross under SR 110 and end at an underground station beneath Raymond Avenue adjacent to the existing Fillmore Station on the Metro Gold Line.

Figure 1-5: LRT Alternative



Two directional tunnels are proposed with tunnel diameters approximately 20 ft each, located approximately 60 ft below the ground surface. Other supporting tunnel systems include emergency evacuation cross passages for pedestrians, a ventilation system consisting of exhaust fans at each portal and an exhaust duct along the entire length of the tunnel, fire detection and suppression systems, communications and surveillance systems, and 24-hour monitoring, similar to the existing LRT system.

Trains would operate at speeds of up to 65 miles per hour (mph) approximately every 5 minutes during peak hours and 10 minutes during off-peak hours.

Seven stations would be located along the LRT alignment at Mednik Avenue in East Los Angeles, Floral Drive in Monterey Park, Cal State LA, Fremont Avenue in Alhambra, Huntington Drive in South Pasadena, Mission Street in South Pasadena, and Fillmore Street in Pasadena. The Fremont Avenue Station, the Huntington Drive Station, the Mission Street Station, and the Fillmore Street Station would be underground stations. New Park-and-Ride facilities would be provided at all of the proposed stations except for the Mednik Avenue, Cal State LA, and Fillmore Street stations.

A maintenance yard to clean, maintain, and store light rail vehicles would be located on both sides of Valley Boulevard at the terminus of SR 710. A track spur from the LRT mainline to the maintenance yard would cross above Valley Boulevard.

Two bus feeder services would be provided. One would travel from the Commerce Station on the Orange County Metrolink line and the Montebello Station on the Riverside Metrolink line to the Floral Station, via East Los Angeles College. The other would travel from the El Monte Bus Station to the Fillmore Station via Rosemead and Colorado Boulevards. In addition, other existing bus services in the study area would be increased in frequency and/or span of service.

As part of the LRT Alternative, the I-710 northbound off-ramp at Valley Boulevard would be modified.

The TSM/TDM Alternative improvements would also be constructed as part of the LRT Alternative. These improvements would provide the additional enhancements to maximize the efficiency of the existing transportation system by improving capacity and reducing the effects of bottlenecks and chokepoints. The only component of the TSM/TDM Alternative improvements that would not be constructed with the LRT Alternative is Other Road Improvement T-1 (Valley Boulevard to Mission Road Connector Road).

1.3.5 Freeway Tunnel Alternative

The alignment for the Freeway Tunnel Alternative starts at the existing southern stub of SR 710 in Alhambra, just north of I-10, and connects to the existing northern stub of SR 710, south of the I-210/SR 134 interchange in Pasadena. The Freeway Tunnel Alternative would include the following tunnel support systems: emergency evacuation for pedestrians and vehicles, air scrubbers, a ventilation system consisting of exhaust fans at each portal, an exhaust duct along the entire length of the tunnel and jet fans within the traffic area of the tunnel, fire detection and suppression systems, communications and surveillance systems, and 24-hour monitoring. An operations and maintenance (O&M) building would be constructed at the northern and southern ends of the tunnel. There would be no operational restrictions for the tunnel, with the exception of vehicles carrying flammable or hazardous materials. As part of both design variations of the Freeway Tunnel Alternative, the I-710 northbound off-ramp and southbound on-ramp at Valley Boulevard would be modified.

The TSM/TDM Alternative improvements would also be constructed as part of the Freeway Tunnel Alternative, including either the dual-bore or single-bore design variations. These improvements would provide the additional enhancements to maximize the efficiency of the existing transportation system by improving capacity and reducing the effects of bottlenecks and chokepoints. The only components of the TSM/TDM Alternative improvements that would not be constructed with the Freeway Tunnel Alternative are Other Road Improvements T-1 (Valley Boulevard to Mission Road Connector Road) and T-3 (St. John Avenue Extension between Del Mar Boulevard and California Avenue).

1.3.5.1 Design Variations

The Freeway Tunnel Alternative includes two design variations. These variations relate to the number of tunnels constructed. The dual-bore design variation includes two tunnels that independently convey northbound and southbound vehicles. The single-bore design variation includes one tunnel that carries both northbound and southbound vehicles. Figure 1-6 illustrates the dual-bore and single-bore tunnel design variations for the Freeway Tunnel Alternative. Each of these design variations is described below.

- **Dual-Bore Tunnel:** The dual-bore tunnel design variation is approximately 6.3 mi long, with 4.2 mi of bored tunnel, 0.7 mi of cut-and-cover tunnel, and 1.4 mi of at-grade segments. The dual-bore tunnel design variation would consist of two side-by-side tunnels (the east tunnel would convey northbound traffic, and the west tunnel would convey southbound traffic). Each tunnel would have two levels with traffic traveling in the same direction. Each tunnel would consist of two lanes of traffic on each level, traveling in one direction, for a total of four lanes in each tunnel. The eastern tunnel would be constructed for northbound traffic, and the western tunnel would be constructed for southbound traffic. Each bored tunnel would have an outside diameter of approximately 58.5 ft and would be located approximately 120 to 250 ft below the ground surface. Vehicle cross passages would be provided throughout this tunnel variation that would connect one tunnel to the other tunnel for use in an emergency situation. Figure 1-6 illustrates the dual-bore tunnel variation of the Freeway Tunnel Alternative.

  Short segments of cut-and-cover tunnels would be located at the south and north termini to provide access via portals to the bored tunnels. The portal at the southern terminus would be located south of Valley Boulevard. The portal at the northern terminus would be located north of Del Mar Boulevard. No intermediate interchanges are planned for the tunnel.

- **Single-Bore Tunnel:** The single-bore tunnel design variation is also approximately 6.3 mi long, with 4.2 mi of bored tunnel, 0.7 mi of cut-and-cover tunnel, and 1.4 mi of at-grade segments. The single-bore tunnel design variation would consist of one tunnel with two levels. Each level would have two lanes of traffic traveling in one direction. The northbound traffic would traverse the upper level, and the southbound traffic would traverse the lower level. The single-bore tunnel would provide a total of four lanes. The single-bore tunnel would also have an outside diameter of approximately 58.5 ft and would be located approximately 120 to 250 ft below the ground surface. The single-bore tunnel would be in the same location as the northbound tunnel in the dual-bore tunnel design variation. Figure 1-7 illustrates the single-bore tunnel variation cross section of the Freeway Tunnel Alternative.

Figure 1-6: Freeway Tunnel Alternative Single and Dual Bore

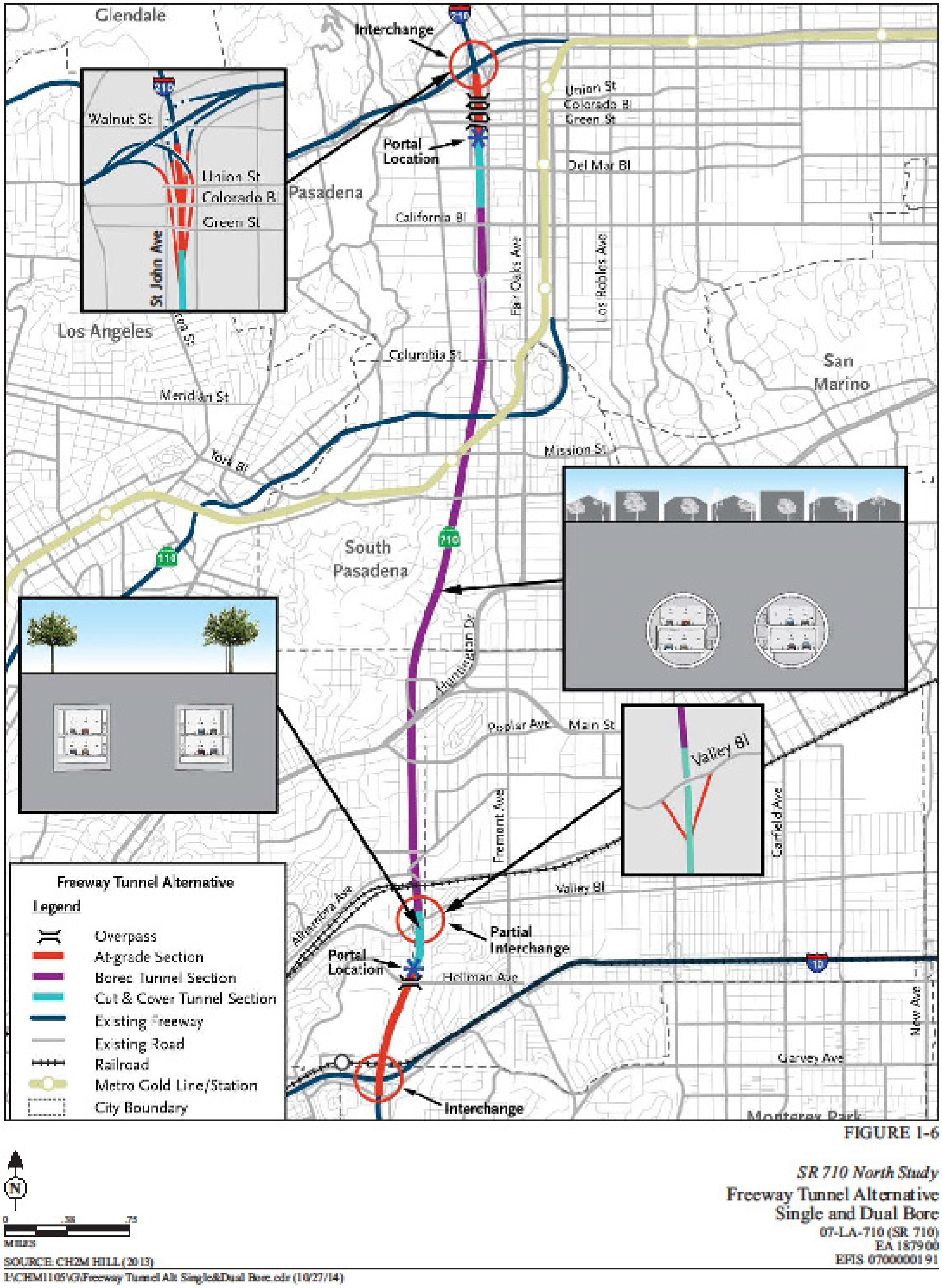


Figure 1-7: Freeway Tunnel Alternative Single Bore Cross-Section

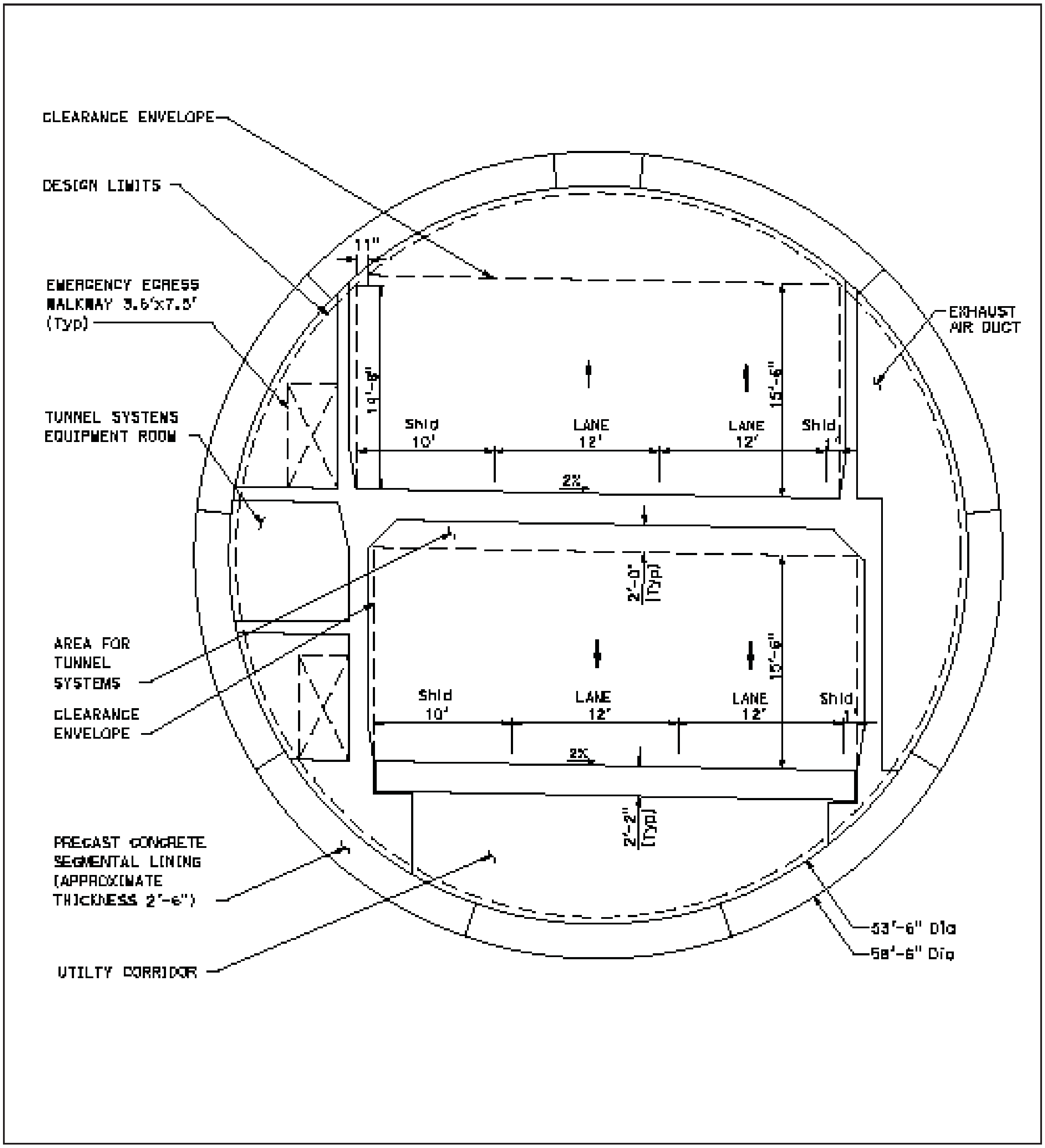


FIGURE 1-7

SR 710 North Study
Freeway Tunnel Alternative
Single Bore Cross Section
07-LA-710 (SR 710)
EA 187900
EFIS 0700000191

SOURCE: CH2M HILL (2014)

I:\CHM1105\G\Single Bore Cross Section.cdr (10/27/14)

1.3.5.2 Operational Variations

There were three different parameters related to the operational variations of the Freeway Tunnel Alternative:

- **Tolling:** Tolls could be charged for vehicles using the tunnel, or it could be free for all drivers (a conventional freeway).
- **Trucks:** Trucks could be prohibited or allowed.
- **Express Bus:** A dedicated Express Bus could be operated using the tunnel. The Express Bus route would start at the Commerce Station on the Orange County Metrolink line, and then serve the Montebello Station on the Riverside Metrolink line and East Los Angeles College before entering I-710 at Floral Drive. The bus would travel north to Pasadena via the proposed freeway tunnel, making a loop serving Pasadena City College, the California Institute of Technology, and downtown Pasadena before re-entering the freeway and making the reverse trip.

The following operational variations have been studied for the Freeway Tunnel Alternative:

- **Freeway Tunnel Alternative without Tolls:** The facility would operate as a conventional freeway with lanes open to all vehicles. Trucks would be allowed and there would be no Express Bus service. This operational variation would be considered for only the dual-bore tunnel design variation.
- **Freeway Tunnel Alternative with Trucks Excluded:** The facility would operate as a conventional freeway; however, trucks would be excluded from using the tunnel. There would be no Express Bus service. Signs would be provided along I-210, SR 134, I-710, and I-10 to provide advance notice of the truck restriction. This operational variation would be considered for the dual-bore tunnel only.
- **Freeway Tunnel Alternative with Tolls:** All vehicles, including trucks, using the tunnel would be tolled. There would be no Express Bus service. This operational variation would be considered for both the dual- and single-bore tunnels described above.
- **Freeway Tunnel Alternative with Trucks Excluded and with Tolls:** The facility would be tolled for all automobiles. There would be no Express Bus service. Trucks would be excluded from using the tunnel. Signs would be provided along I-210, SR 134, I-710, and I-10 to provide advance notice of the truck restriction. This operational variation would be considered for the single-bore tunnel only.
- **Freeway Tunnel Alternative with Toll and Express Bus:** The freeway tunnel would operate as a tolled facility and include an Express Bus component. The Express Bus would be allowed in any of the travel lanes in the tunnel; no bus-restricted lanes would be provided. Trucks would be permitted. This operational variation would be considered for the single-bore tunnel only.

Executive Summary

2.1 Introduction

An evaluation of operational groundborne noise and vibration due to operation of LA Metro revenue trains inside the LRT tunnel alignment and from motor vehicle traffic inside the Freeway tunnel alignment was conducted. Groundborne noise and vibration levels from both transportation modes have been projected for the interiors of occupied buildings adjacent to the planned rail and freeway alternative tunnel alignments. This report discusses all of the testing and the analysis conducted for the two tunnel alignments, groundborne noise and vibration impact analysis and preliminary indications of feasible mitigation measures, where necessary, to reduce groundborne noise and/or vibration levels to achieve the appropriate criteria.

Groundborne noise and vibration predictions contained herein are based on an empirical model developed for the U.S. Department of Transportation and adopted by the Federal Transit Administration (FTA). The environmental noise and vibration criteria used in this analysis are contained in the FTA publication *Transit Noise and Vibration Impact Assessment* (Ref. 1), which is sometimes referred to as the FTA Guidance Manual. The resulting groundborne noise and vibration predictions and potential mitigation, as determined by the vibration prediction model and applicable criteria, form the basis of the groundborne noise and vibration impact assessment for the two tunnel alignments of the SR710 project.

2.2 Results of Groundborne Noise and Vibration Analysis

Predictions models for groundborne noise and vibration were developed for the LRT and Freeway tunnel alignment alternatives using project-specific data measured in the SR710 corridor along the proposed alignments. Other sources of data were also used to develop the necessary model parameters.

2.2.1 LRT Groundborne Noise and Vibration Impacts and Mitigation

Results of the analysis for operational groundborne noise and vibration for the LRT tunnel alignment indicate several areas of impact to residential land uses. The groundborne noise predictions indicate that four hundred and fifty-four (454) residential buildings and one (1) commercial office building would be impacted. With the mitigation determined from the analysis, all groundborne noise impacts would be eliminated. All of the mitigation measures evaluated involve standard vibration control applied at the track level. Furthermore the analysis indicated there would be no groundborne vibration impacts.

2.2.2 Freeway Groundborne Noise and Vibration Impacts

Results of the analysis for operational groundborne noise and vibration for the Freeway tunnel alignment indicated that there would be no groundborne noise and vibration impacts.

2.2.3 Construction Vibration Impacts

Results of the analysis indicate there could be short-term construction vibration impacts during tunnel boring lasting as long as three (3) days when the tunnel was constructed directly below sensitive receptors such as residences. The results also indicate there could be longer term construction noise impacts from groundborne vibration associated with supply train movements, which could be mitigated where necessary by scheduling them during daytime hours. There could also be longer term construction impacts associated with muck train movements to remove spoils that could partially be mitigated by track level mitigation measures such as ballast mats under the rails.

There may also be vibration impacts during the construction of stations where there are residences nearby. Pile driving and other vibration producing activity at station sites may impact residential receptors within 200 feet of the construction activity. Best management practices and vibration monitoring to limit vibration at these receptors can be employed to minimize if not eliminate vibration impacts. Where vibration impacts cannot be avoided there may be short-term construction impacts around the stations sites.

Settings

3.1 Operational Groundborne Noise and Vibration Impact Criteria

The environmental, groundborne noise and vibration impact evaluation for operational impacts conducted in support of the SR710 DEIR/DEIS was based on a prediction of noise and vibration levels and their comparison to the FTA noise and vibration impact assessment criteria (Ref. 1). FTA recognizes three levels of vibration analysis based on the level of specificity of available details regarding the project and the local conditions along the proposed transit alignment. The highest level of analysis is a vibration screening. A screening analysis was conducted for the SR710 screening study (Ref. 2). A screening analysis generally indicates areas of concern along the proposed alignment alternatives, but does not quantify the level of impact. The distance used for screening was 150 feet for residential land uses from centerline of the tunnel alignment. Following a screening analysis a general vibration assessment level of impact analysis is typically appropriate if no site specific data are available other than alignment and the general soil types and properties. A general assessment is by nature generic, but does provide an indication of impact levels.

Where the alignment options have been narrowed to one or two, the design has progressed sufficiently and specific alignment details are available, and vibration testing along the alignment is possible, a more site-specific analysis can be conducted to obtain a more accurate assessment of potential impacts. This level of analysis is referred to as a detailed vibration analysis. A detailed analysis provides a more accurate indication of impact levels than the general vibration assessment. Where impacts are indicated by the detailed analysis, further analysis can be conducted in the Preliminary and Final Engineering phases of the project to further refine site-specific vibration propagation characteristics in areas identified during the environmental process as impacted and needing mitigation. Such studies during later stages of engineering can also be used to refine the mitigation measures required.

Predicted levels of groundborne noise and vibration have been evaluated using the FTA criteria, according to the Land Use Categories defined in Table 3-1, which indicates the criteria to be used in a detailed analysis. The vibration criteria indicated in Table 3-1 are based on the 1/3-octave band levels. However, if the overall vibration level does not exceed the relevant criterion then neither does any of the 1/3-octave levels. Hence it is sufficient to evaluate just the predicted overall vibration levels, unless the criteria are exceeded, in which case an evaluation of the 1/3-octave levels is then warranted.

No receivers along the alignment have been identified that can be classified under Land Use Category 1. Such receivers would include vibration-sensitive manufacturing, research, or special medical facilities. The majority of receivers within the LRT alignment corridor are Land Use Category 2. Category 2 receivers include residential land uses and those where people sleep at night (e.g., hotels and hospitals). The FTA criteria for Category 2 receivers are 35 dBA for groundborne noise and 72 VdB (re: 10^{-6} in/sec) for vibration. Institutional land uses under Category 3 with daytime uses only (e.g. schools and churches) have criteria of 40 dBA for groundborne noise and 75 VdB for vibration. Category 3 also applies to “quiet office” spaces such as doctor’s offices and some commercial spaces where quiet is important to occupants. In general, commercial (except for “quiet offices”) and industrial land uses are not considered to be noise and vibration sensitive receptors according to the FTA criteria.

Table 3-1 Groundborne Vibration and Groundborne Noise Impact Criteria for Detailed Analysis

Land Use Category	GBV Impact Levels (VdB re 1 micro-inch/sec)			GBN Impact Levels (dB re 20 micro-Pascals)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations	65 VdB[4]	65 VdB[4]	65 VdB[4]	N/A[4]	N/A[4]	N/A[4]
Category 2: Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB	35 dBA	38 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA

Notes:

1. "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category
2. "Occasional Events" is defined as 30 to 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3. "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.
4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
5. Vibration-sensitive equipment is not sensitive to ground-borne noise.

An alignment may also include specific receivers (auditoriums or theaters) that are considered to be Special Land Uses for groundborne noise and vibration impacts. The criteria for these land uses are shown in Table 3-2. No special land uses have been identified within 450 feet of the SR710 tunnel alignments.

Table 3-2 Criteria for Special Land Use Categories

Type of Building or Room	GBV Impact Levels (VdB re 1 micro-inch/sec)		GBN Impact Levels (dB re 20 micro-Pascals)	
	Frequent Events[1]	Occasional or Infrequent Events[2]	Frequent Events[1]	Occasional or Infrequent Events[2]
Concert Halls	65 VdB	65 VdB	25 dBA	25 dBA
TV Studios	65 VdB	65 VdB	25 dBA	25 dBA
Recording Studios	65 VdB	65 VdB	25 dBA	25 dBA
Auditoriums	72 VdB	80 VdB	30 dBA	38 dBA
Theaters	72 VdB	80 VdB	30 dBA	43 dBA

Notes:

1. "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2. "Occasional or Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
3. If the building will rarely be occupied when trains are operating, there is no need to consider impact. As an example, consider locating a commuter rail line next to a concert hall. If no commuter trains will operate after 7 pm, it should be rare that the trains will interfere with the use of the hall.

3.2 Construction Vibration Impact Criteria

FTA (Ref. 1) provides criteria for two types of impact from construction vibration. They are impacts due to annoyance and impacts due to building damage. For evaluating annoyance impacts the criteria presented above in Section 3.1 are applicable. Construction impacts can result in short term annoyance and can be classified as Infrequent Events as indicated in Table 3-1 above. Construction vibration damage criteria from FTA (Ref. 1) are provided in Table 3-3.

Table 3-3 Construction Vibration Damage Criteria

Building Category	**PPV (in/sec)**	**Approximate Lv†**
I. Reinforced-concrete, steel or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry building	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90
†RMS velocity in decibels (VdB) re 1 micro-inch/second		

FTA recommends a damage criterion of 0.12 in/sec for buildings that are extremely susceptible to vibration, which would include fragile historic buildings. At this level of vibration an historic building that is fragile may suffer cosmetic damage, characterized by fine plaster cracking and the re-opening of old cracks. There are no known historic buildings within the study area that are close enough to experience levels of this magnitude. However, if such buildings are discovered then compliance with this vibration limit will minimize damage to such buildings.

3.3 Impacts to Historic Properties

Vibration impacts to historic properties can occur due to groundborne noise and vibration affecting the normal use of such properties, but only for indoor activities. Outdoor activities are not impacted by groundborne noise or vibration. Consequently potential vibration impacts to historic properties from operation are limited to historic buildings that are occupied. Normal use of a historic building is generally defined by the building's current use, such as a residence (i.e., a building with nighttime occupancy). Another example might be an office that occupies a former residence, in which case the normal use would be as an office. The operational vibration impact analysis reported herein, includes all buildings close enough to be potentially impacted taking into account their sensitivity to groundborne noise and vibration based on the current usage. Hence impacts identified in Section 5 include all impacts to historic buildings, although these buildings have not yet been identified. Once the cultural impact report is completed, and the historic buildings within the vibration study area are identified, the historic buildings impacted by operational groundborne noise or vibration will be listed and/or labeled. Generally any historic building more than 200 feet from the alignment will not be impacted by operational groundborne noise and vibration, unless it is a special building such as a concert hall of which there are none in the vibration study area. Potential operational groundborne noise effects on historic resources will be evaluated as part of the Section 106 process.

Construction vibration may in rare cases lead to physical damage to historic structures if not properly limited. The structure may be a building or a freestanding structure such as a monument. Operational vibration is sufficiently low in magnitude as to pose no risk of damage to structures. Generally construction vibration impacts are short-term and do not typically lead to impacts that would affect the normal use of historic properties, in particular if proper limits are imposed on construction vibration. The same is true of construction vibration, which can be sufficiently mitigated by imposing proper vibration limits that avoid damage. Some historic structures are more fragile than others (in particular old masonry), hence the vibration limits should reflect the nature of structure's construction and also the state of maintenance of the structure. Potential construction vibration effects on historic resources will be evaluated as part of the Section 106 process.

The preliminary assessment of Historic Properties has identified residential buildings along the tunnel alignment. These properties will be documented in the Historic Property Survey Report. The historic buildings that are close enough to be impacted by vibration during construction are essentially all residential structures. During tunnel boring, vibration is predicted to be low enough to avoid structural damage to older residential buildings.

During tunnel boring, minor cosmetic damage (hairline cracks) to older buildings poses a low risk. This would apply only to those residences built prior to 1940 and only those where interior walls are constructed with lath and plaster, which in general started to fall out of use starting in 1920. By 1930 lath and plaster had essentially been replaced with drywall (gypsum wallboard) construction.

During the engineering phase of the project a more detailed assessment of the potential for damage will be conducted for all buildings including historic properties at which time the details concerning methods of tunnel boring and excavation will be more clearly defined an in much greater detailed. At this phase of the project the potential for damage due to tunnel boring is predicted to be low. The potential for damage during excavation at tunnel portals, stations and vent shafts is higher due to the use of driven piles. During engineering design, if this impact is determined to exist for specific structures it can be mitigated by the use of pre-drilled piles or soil mix wall construction.

4 Prediction Methodology

4.1 FTA Methodology

The methodology used for predicting future, interior vibration and groundborne noise levels from transit train operations was developed during an extensive research project conducted for the United States Department of Transportation and is discussed in detail in the paper *A Prediction Procedure for Transportation Groundborne Noise and Vibration* (Ref. 3). This prediction procedure is the basis for the methodology recommended by the FTA (Ref. 1), and has been used in the United States for evaluating the environmental effects of numerous new transit projects for over 26 years. The prediction methodology is based on the assumption that the generation of vibration by a train and the propagation of that vibration through soil and buildings can be broken into independent elements, each of which can be quantified separately. The individual elements are combined to predict groundborne noise and vibration.

4.2 Prediction Model for Operational Groundborne Vibration

The following discussion pertains specifically to the LRT tunnel alignment, but in general the discussion applies also to the freeway tunnel alignment with the difference being the vehicles involved and the manner in which vibration is imparted to the tunnel. For motor vehicles, there are no tracks; the vibration is imparted to the tunnel structure at the tire/roadway interface, otherwise the modeling approach is the same.

The FTA prediction model for groundborne vibration employs the following equation:

$$L_v = FDL + LSR + BVR + AF$$

where: L_v = Projected vibration velocity level in a specific building - VdB
FDL = "Force Density Level" - dB Re: 1 lb/ft$^{1/2}$
LSR = "Line Source Response" - dB Re: 10^{-6} (inch/sec)/(lb/ft$^{1/2}$)
BVR = "Building Vibration Response" - dB (relative level)
AF = "Adjustment Factor" for track and structure - dB (relative level)

General descriptions and importance of the prediction model parameters are discussed below. Further details and the derivation of each parameter are discussed in Section 4.4. All of the calculation parameters employ 1/3-octave bands to ascertain the frequency content of the vibration. The "overall" vibration level at a building location is the combination of the individual 1/3-octave band spectrum levels determined by an energy sum over all the bands. The energy sum results in a single-number level (also in decibels - VdB) accounting for the vibration energy in all of the 1/3-octave bands. The FTA General Assessment vibration criteria are based on the overall vibration levels, whereas the Detailed Assessment criteria are based on the individual 1/3-octave band levels.

Each projection of groundborne vibration begins with the FDL, which essentially represents an incoherent line source of vibration forces generated by the dynamic interaction of the transit vehicle and the track support system. The LSR indicates vibration velocity levels at a receiver location relative to the FDL, and represents the response of the local soil strata to vibration and the attenuation of vibration energy due to propagation through the surrounding soil. The LSR is added to the FDL to predict the ground surface vibration velocity levels in the absence of buildings.

The BVR represents the response of a particular building or type of building structure relative to ground vibration. The response of the building includes the "foundation coupling loss", floor-to-floor attenuation and resonant amplification of vibrating room surfaces (floors/ceilings and walls) that may apply to a specific receiving area.

To predict groundborne noise and vibration levels for conditions other than continuous welded track, an Adjustment Factor (AF) is applied to account for the effects of special trackwork, such as crossovers and turnouts, and the specific alignment structures, such as retained cuts, embankments, tunnel geometry and construction type (bored vs. cut-and-cover; single- vs. double-box) on the vibration propagated to the wayside.

Where projected vibration levels exceed criteria, it is necessary to consider mitigation and account for the vibration reduction performance of potential measures. To accomplish this, an "Insertion Loss" (IL) in decibels (VdB) is added to the projected vibration levels, with the result being the mitigated vibration level. The IL is expressed in relative decibels between the vibration level with mitigation and the vibration level without mitigation (i.e. the proposed track design).

$$L_{v\ (w/\ mitigation)} = L_{v\ (no\ mitigation)} + IL$$

where: IL = Insertion loss for vibration mitigation - dB (relative level)

An IL with a negative value represents a reduction in vibration velocity while a positive IL represents an increase in vibration level.

4.3 Prediction Model for Operational Groundborne Noise

Groundborne noise is noise generated by vibrating building surfaces such as floors, walls, and ceilings that radiate noise inside buildings when the source of the vibration is exterior to the building. In this case, of course, the source is the transit system. Groundborne noise is commonly described as the rumble one hears from a subway train, and the estimation of such noise follows the prediction of interior surface vibration.

The final step in the groundborne noise and vibration prediction procedure is the prediction of noise levels in a receiving room due to acoustic radiation by the room's vibrating elements. The following relation (Ref. 1) has been used for converting 1/3-octave band vibration velocity levels to 1/3-octave noise levels:

$$L_A = L_v + K_{rad} + K_{A\text{-}wt}$$

Where:
- L_A = sound pressure level (dB re: 20 micro-Pa)
- L_v = vibration velocity level (dB re: 1 micro-inch/sec)
- K_{rad} = adjustment to account for conversion from vibration to sound pressure level accounting for the acoustical absorption in the room.
- $K_{A\text{-}wt}$ = A-weighting adjustment at the 1/3-octave band frequency.

The calculation of K_{rad} can be determined from the following (Ref. 3):

$$K_{rad} = -(10\ \mathrm{Log}_{10}(\alpha) + 1)$$

Where: α = average absorption coefficient for room in 1/3-octave band.

For this analysis, an absorption coefficient of 0.4 has been used, resulting in a net conversion factor from 1/3-octave band vibration levels to 1/3-octave band noise levels of K_{rad} = 3 dB. Reference 3 includes detail and measured data relating to the conversion of groundborne vibration to noise levels, and +3 dB is a reasonable adjustment to include.

4.4 Derivation of Prediction Model Parameters

The FTA model is an empirical model, which means that all of the elements are obtained from conducting field measurements.

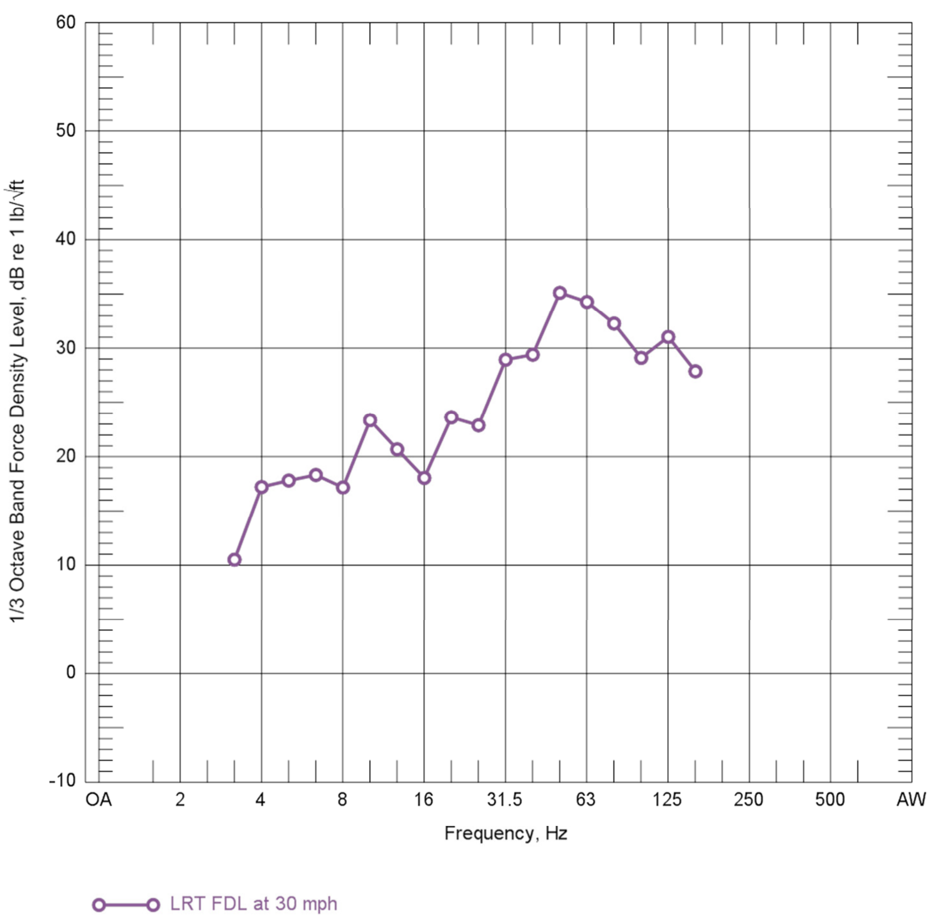
4.4.1 Force Density Level

The force density level (FDL) defines the amount of dynamic force transmitted to the tunnel structure by the vehicle and any intervening devices such as the rail and its fastening system in the case of an LRT train or the wheels of a motor vehicle such as a truck. FDL's are obtained by field measurements on similar vehicles and systems to those proposed for the project being analyzed.

4.4.1.1 LRT Force Density Level

The FDL for the LRT was obtained from Reference 5. This FDL is based on several past measurements conducted on the various lines of the LA Metro LRT system and supplemented with measurements made in Seattle for Sound Transit. The FDL in Reference 5is for an LRT train speed of 30 mph. The operating speed of the SR710 LRT will vary depending on its location along the alignment. A speed profile (Ref. 6) for the project was provided to define LRT speeds along the alignment. The FDL was adjusted to reflect speed using the factor $20*Log_{10}(S_{LRT}/30)$, where S_{LRT} is the speed of the LRT at any point along the tunnel alignment. This is a commonly used adjustment factor for speed. Based on this information, the FDL spectrum for the analysis was selected as shown by the curve in Figure 4-1.

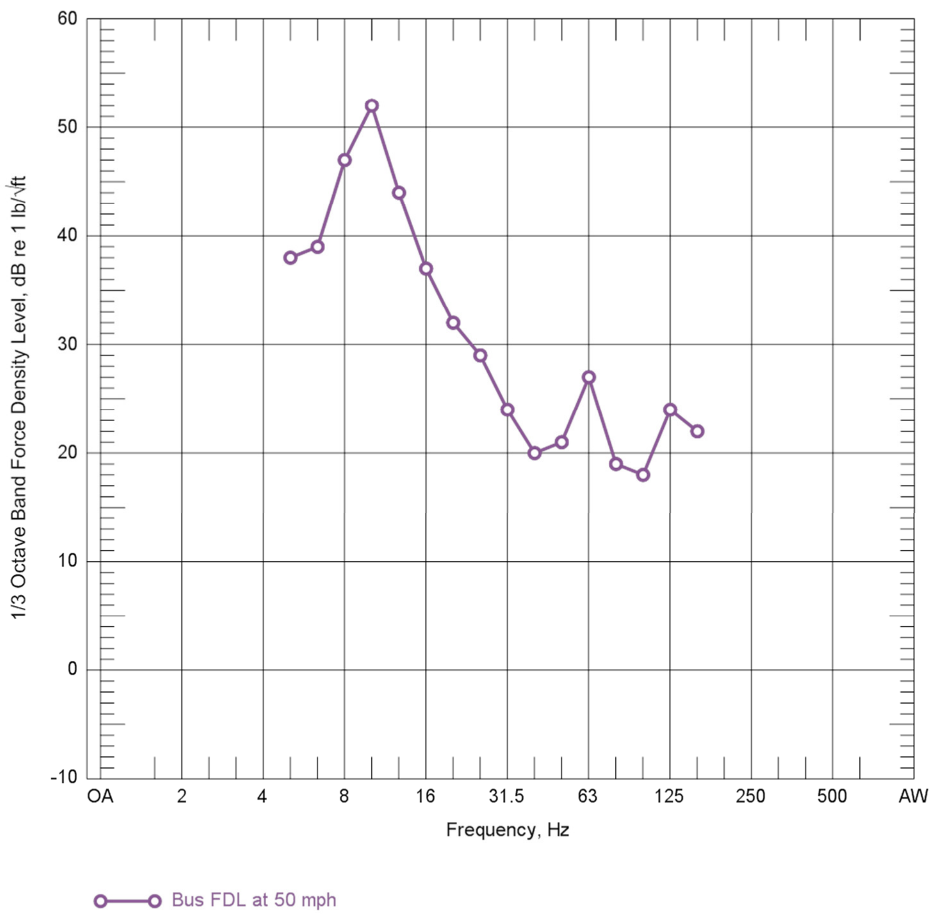
Figure 4-1 FDL for Light Rail Vehicle



4.4.1.2 Motor Vehicle Force Density Level

The FDL for heavy motor vehicles such as trucks is based on field measurements performed on large city buses which have similar suspension and axle loads to heavy trucks. Automobiles will have an FDL that is less than this and therefore generate lower vibration. The FDL for a bus was obtained from Reference 7. This FDL was adjusted for speeds up to 50 mph by linear extrapolation of the data contained in this reference. The FDL used in the analysis for vibration to represent heavy motor vehicles is shown in **Error! Reference source not found.**. The peak in the FDL spectrum is at 10 Hz, which is associated with the vehicle's suspension.

Figure 4-2 FDL for Heavy Motor Vehicle.



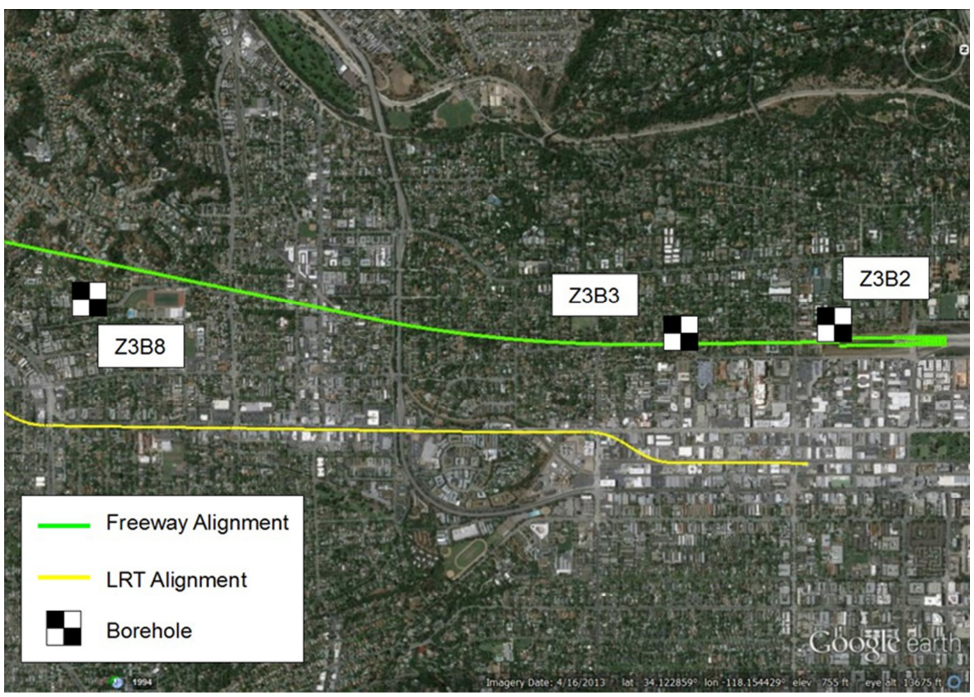
4.4.2 Line Source Response

When constructed the LRT tunnel or the freeway tunnel for the SR710 project would be bored in a geologic formation that is characterized primarily by stiff strata, which includes various regions of siltstone (Fernando formation), sandstone (Topanga formation), a combination of siltstone, claystone, mudstone, shale and sandstone (Puente formation) or diorite and gneiss (crystalline basement rock) (Ref. 8). In some areas the stiff strata are overlain by alluvial deposits primarily sand and gravel. Except for near the portals, the LRT tunnel would be approximately 70 to 80 feet below the surface, whereas the freeway tunnel would be considerably deeper at typically 150 feet, but in some cases up to 200 feet below the surface.

Vibration testing was conducted for the SR710 project alignment for the purpose of obtaining representative line source response (LSR). The testing was conducted using water monitoring wells for the project. Soils data contained in the geotechnical report (Ref. 8) was reviewed to select which monitoring wells to use in order to get a representative sampling of different soil conditions (i.e., soil type and strata). Soil vibration propagation characteristics were measured at seven (7) monitoring well locations. The selection of test locations also took into account the local concentration of sensitive receivers for groundborne noise and vibration and the proximity of wells to these receivers. The locations of these vibration propagation test locations are shown in Figure 4-3 and Figure 4-4.

Figure 4-3 Vibration Propagation Test Locations in Southern Portion of Alignment

Figure 4-4 Vibration Propagation Test Locations in Northern Portion of Alignment



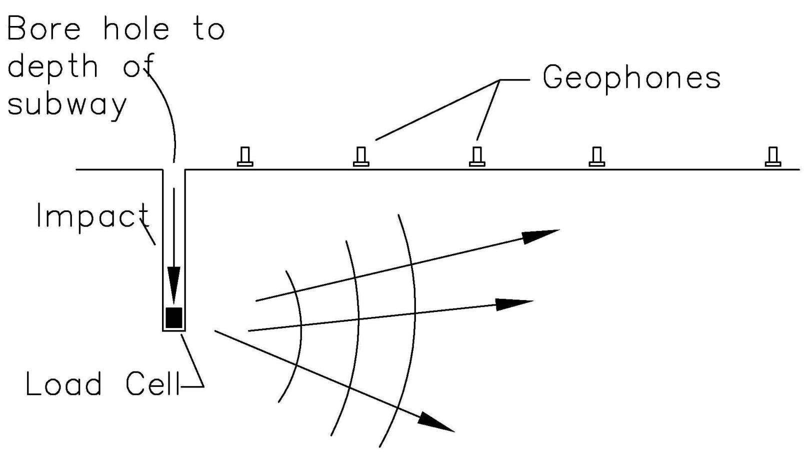
Line source response refers to the response of a free ground surface, not to the response of a built surface, such as a floor.[1] The LSR characterizes the vibration velocity response at a single location to incoherent forces

[1] The line source response is not the attenuation with distance from a given reference location. Although the LSR usually decreases with distance (exceptions are rare and occur only over short distances), and the 1/3-octave band values are typically positive.

distributed over the length of a train or transit vehicle (i.e., a finite line source). In practice, the LSR for a soil region is measured by imparting a vertical force on the ground surface or at the bottom of a borehole (for subsurface alignments), measuring the force with a load cell or strain gauge, and simultaneously measuring the vertical vibration velocity of the ground surface at multiple distances from the impact location. This procedure provides point source responses (PSR), or point transfer mobilities, from which a line source response can be constructed through integration over a line and curve fitting of the data.

The typical procedure for collecting transfer mobility data is to impact the ground and measure the ground surface velocity at six or seven distances using geophones. For subway alignments, a force-instrumented transducer is attached to end of a drill string and the impacts delivered by a standard, 130-pound driller's slide hammer. This procedure requires drilling a 5-inch diameter hole and halting the drilling to perform testing at the various depths of interest. The impact force generated by the hammer and the corresponding geophone responses are recorded simultaneously for 40 to 50 impacts at each testing depth. A graphic representation of the borehole test is presented in Figure 4-5.

Figure 4-5 Line Source Response Test – Impact at Bottom of Borehole

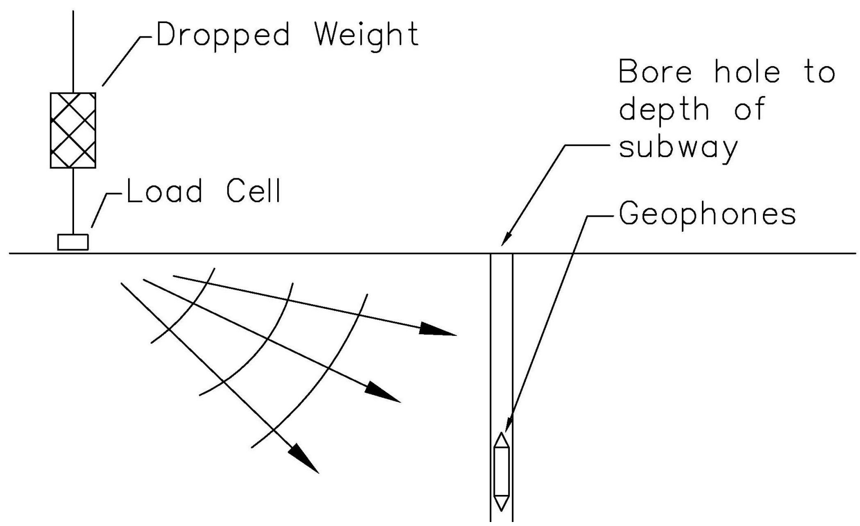


For the SR710 project pre-drilled, water monitoring wells were used to conduct the vibration propagation field tests instead of drilling new boreholes. In order to obtain data for more than one depth below the surface, an alternative procedure to impacting at the bottom of the borehole was used. This alternative procedure makes use of the principle of reciprocity, in which the ground surface is impacted at multiple locations instead and the velocity response at a specific depth in the borehole using a down-hole geophone is measured. The result is a similar measurement of the transfer mobility from one point to another, but the point of impact and the point of response are switched.

The principal of reciprocity, a standard principal from the theory of elasto-dynamics, dictates that the transfer mobility (response velocity /input force) at tunnel depth due to forces imparted to the ground surface should be identical to the transfer mobility measured from the response of the ground surface to forces applied at tunnel depth. That is, the transfer mobility results are identical if the force and velocity response measurement locations are swapped. By using reciprocity, the response at each of the source locations due to a force at any specific depth in each of the boreholes should be equal to those measured during the test using reciprocity. This was confirmed by forward tests (traditional method) and concurrent reciprocal tests conducted for Sound Transit in Seattle, Washington (Ref. 9).

The principal of reciprocity greatly simplifies the test procedure and reduces the time required for testing. It also allows for measurements to be made at more than one depth in pre-drilled holes. Figure 4-6 depicts the test configuration using the principle of reciprocity to obtain vibration propagation data (i.e., transfer mobilities).

Figure 4-6 Line Source Response Test Using Reciprocity Technique for Transfer Mobility



Before constructing LSRs from the transfer mobility data, the data were checked for typical relationships between depths and locations, for responses similar to those determined previously for similar soil strata, and for repeatability and coherence in the measured responses. Transfer mobility data collected by the borehole vibration testing were then fit with polynomial functions of distance using least squares regression over the two sets of data (i.e., two different depths at each borehole). The point source responses that are derived from the curve fitting were then numerically integrated over the length of a three-car LRT train to obtain the following mathematical function for the line source response with distance:

$$LSR(x,z) = A + B \cdot Log(s) + C \cdot z + D \cdot x$$

Where: A, B, C, D = polynomial coefficients
x = horizontal distance from track centerline to receiver building façade
z = depth to track from foundation of receiver
s = slant distance from track = $\sqrt{x^2 + z^2}$

Vibration test locations, dates and testing depths for the seven wells tested are shown in Table 4-1. Detailed data for all of the LSRs used in the SR710 alignment analysis, including the polynomial fit coefficients, are provided in the Appendix.

Table 4-1 Vibration Propagation Test Locations

Vibration Test Well	Test Date	1st Depth (ft)	2nd Depth (ft)
Z1B8	3/18/2013	50	140
Z4B4	3/21/2013	50	140
Z2B5	3/20/2013	50	140
Z3B12	3/20/2013	50	140
Z3B8	3/19/2013	43	85
Z3B3	3/21/2013	50	140
Z3B2	3/18/2013	50	140

Table 4-2 and Table 4-3 list the assignment of specific LSRs in the vibration prediction model to the LRT tunnel alignment and freeway tunnel alignment, respectively. LSR spectra were applied in the vibration prediction model on a receiver-by-receiver basis. The LSR for each receiver was selected from the body of calculated spectra according to the receiver's proximity to the seven testing locations as well as the local geology. The field station ranges for each LSR were determined by comparing subsurface layers indicated in the geotechnical data (Ref 8).

Table 4-2 LSR for LRT Tunnel Alignment

LRT Field Station Range	LSR
167+00 - 188+00	Z1B8
188+00 - 224+00	Z4B4
224+00 - 236+00	Z2B5
236+00 - 275+00	Z3B12
275+00 - 297+00	Z3B8
297+00 - 350+00	Z3B3
350+00 - 382+00	Z3B8
382+00 - 398+00	Z3B3
398+00 - 415+00	Z3B2

Table 4-3 LSR for Freeway Tunnel Alignment

Freeway Field Station Range	LSR
1439+00 - 1507+00	Z1B8
1507+00 - 1534+50	Z2B5
1534+50 - 1570+50	Z3B12
1570+50 - 1629+00	Z3B8
1629+00 - 1716+50	Z3B3
1716+50 - 1739+80	Z3B2

4.4.3 Building Vibration Response

There are several factors related to a building's structure that act to either attenuate or amplify groundborne vibration. The three main components are (1) soil/foundation coupling loss, (2) floor-to-floor attenuation, and (3) floor resonance amplification due to vibration. In total, the combination of these effects is called the building vibration response.

Some of the residential use buildings along the SR710 tunnel alignments are constructed with slab-on-grade ground floors and wood framed floors above. This combination is particularly common for buildings with commercial uses on the ground floor and residential above. In these buildings, a net decrease in vibration transmission results at the ground floor slab from coupling losses at the slab-to-soil boundary, but the wood framed upper floors sometimes exhibits a net amplification in vibration away from the walls, with the greatest amplification experienced at the second floor.

In contrast to those residential buildings with a slab-on-grade ground floor, most of the single-family residential buildings along the SR710 alignment are constructed with a raised ground floor (wood framing). Because of the closer vertical distance to the soil, and the lighter-weight framing of these buildings compared to multifamily residential structures, single-family homes with a raised ground floor ultimately show the greatest amplifications in their BVR spectra.

BVR spectra for all of the buildings along the SR710 tunnel alignment were assigned based on the observations of usage, building types and construction from the alignment survey and use of Google Earth's StreetView. Generic building response data are contained in Reference 3 and in Reference 4. However, a substantial database of BVR data for wood frame buildings, in particular residential buildings, is available in Reference 10. The SR710 project vibration analysis used selected data from this reference.

Three spectra were used in the analysis and are defined as follows:

- SOG = Slab-on-grade floor
- SF = Single-family residence with raised first floor or second floor
- MF = Multi-family residence with multiple stories

The SOG BVR spectrum assumes that the building construction provides zero (0) dB of amplification at all frequencies. The SF and MF BVR spectra were obtained by averaging BVR spectra in Reference 10. The BVR used in the analyses are shown in Figure 4-7, Figure 4-8, and Figure 4-9.

Figure 4-7 BVR for Single Family Residence with Slab-on-grade Floor

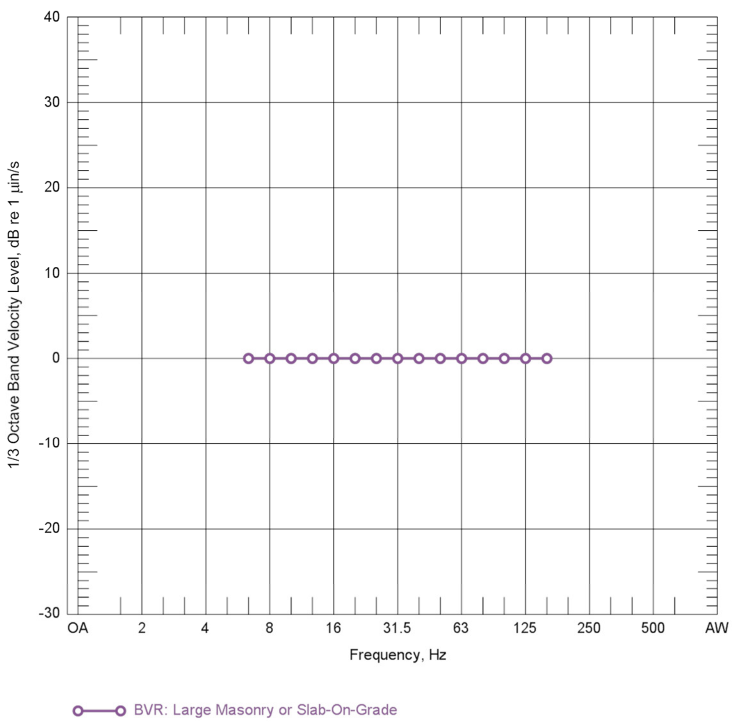


Figure 4-8 BVR for Single Family Residence with Raised Floor Foundation

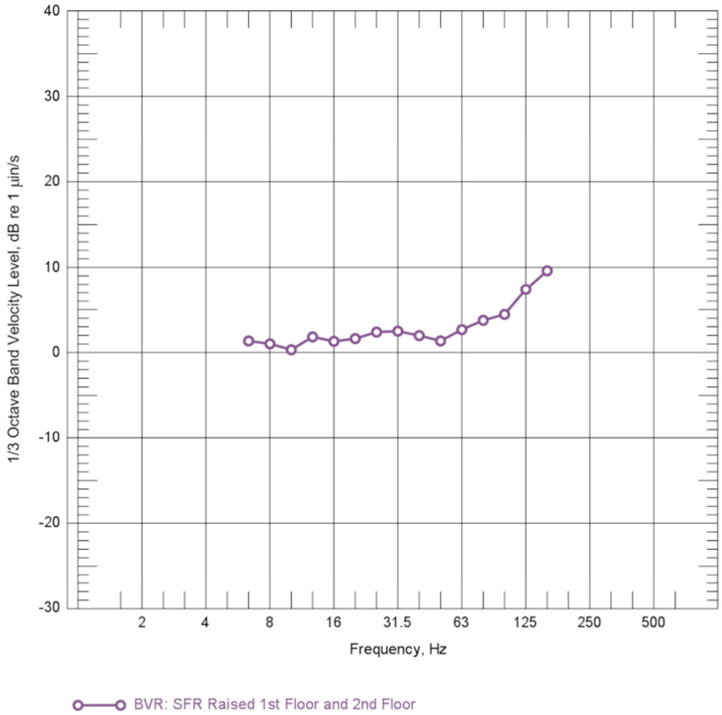
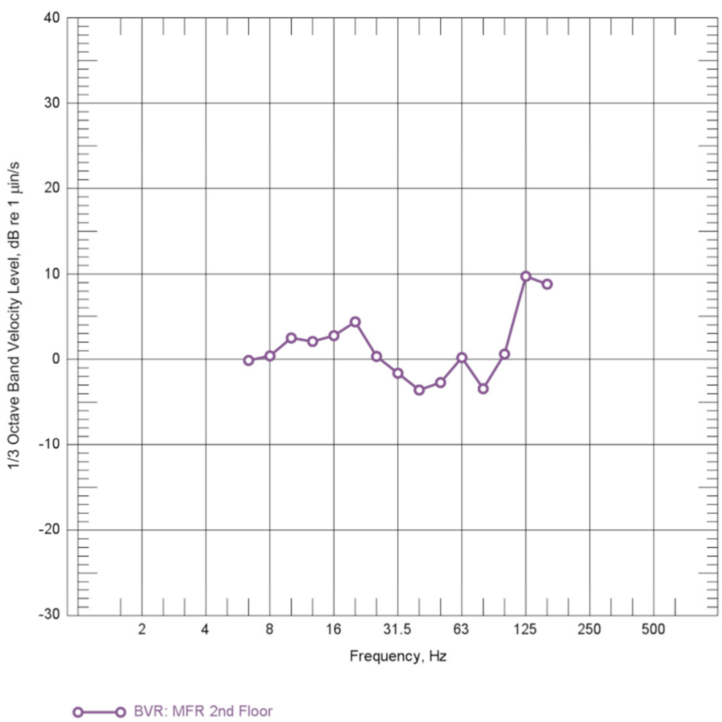


Figure 4-9 BVR for Multifamily Residence



4.4.4 Adjustment Factors

Adjustments for the tunnel structure were unnecessary considering the high stiffness of the soil in which the tunnel structure will be constructed. An adjustment was necessary for "special trackwork" (e.g. crossovers and turnout switches) for the SR710 tunnel LRT alignment. The special trackwork, adjustment factor accounts for the ground vibration levels in the immediate vicinity of a crossover, which will be higher than for track segments without crossovers. The higher vibration levels are generated by wheel impacts as the wheels cross rail gaps at the frogs. This additional source of vibration acts like a point source at each frog and increases the wayside vibration levels. The following adjustments were applied for receptors in the vicinity of crossover and turnout switch frogs:

$AF_{Crossover} = +\ 11$ dB	distances (slant) < 20 feet from a frog
$AF_{Crossover} = +\ [11 - 20\ \mathrm{Log}(distance/20)]$ dB	20 feet ≤ distance ≤ 70 feet
$AF_{Crossover} = +\ 0$ dB	distances > 70 feet from all frogs

5 Operational Impacts from Groundborne Noise and Vibration

5.1 LRT Tunnel Alignment

The groundborne noise and vibration impacts along the SR710 LRT tunnel alignment were evaluated using the FTA criteria (Ref. 1). All residential land uses identified along the alignment were treated individually in the groundborne noise and vibration prediction model. Institutional land uses (e.g., schools) and quiet offices were also treated individually in the calculations. The projected levels of groundborne noise and vibration for LRT train operations within the tunnel alignment were calculated using the prediction models described in Sections 4.2 and 4.3. Predicted groundborne noise and vibration levels are presented as a range of expected values.

The predicted groundborne noise and vibration levels are compared to the FTA criteria. Determination of impact and mitigation measures where needed and their extents are based on the upper value in each range. The analysis indicates predicted groundborne noise levels exceeding the FTA criteria at many locations. No vibration impacts are predicted for the LRT tunnel alignment according to the predicted levels compared with the FTA vibration criteria.

5.1.1 Groundborne Noise and Vibration Impacts

The projected levels of the groundborne noise from the analysis for the LRT tunnel alignment are shown in Table 5-1. The predicted groundborne noise levels are compared to the appropriate FTA criteria. The shaded cells indicate exceedance of criteria and therefore impacts. The mitigation necessary to mitigate impact is indicated by heading at the top of the cells that are not shaded.

Table 5-1 Groundborne Noise Impacts for LRT Tunnel Alignment

Key: GBN = Groundborne noise – IMPACTS ARE HIGHLIGHTED
HRDF = Highly Resilient Direct Fixation Fasteners
RSF = Rail Suspension Fasteners
IST = Isolated Slab Track
FST = Floating Slab Track

Civil-Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA Criteria (dBA)	GBN Range Without Mitigation (dBA)	# of Impacts Without Mitigation	GBN with HRDF (dBA)	GBN with RSF (dBA)	GBN with IST (dBA)	GBN with FST (dBA)
167+00	1809 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	201	0	35	17 to 20	-	-	-	-	-
167+00	1805 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	149	0	35	21 to 24	-	-	-	-	-
167+00	1801 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	126	0	35	23 to 26	-	-	-	-	-
167+00	1725 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	133	0	35	22 to 25	-	-	-	-	-
167+00	1721 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	130	0	35	22 to 25	-	-	-	-	-
167+50	1717 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	130	0	35	22 to 25	-	-	-	-	-
168+50	1715 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	63	9	35	33 to 36	1	28 to 31	-	-	-
168+50	1709 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	63	9	35	33 to 36	1	28 to 31	-	-	-
169+00	1705 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	64	13	35	33 to 36	1	28 to 31	-	-	-
169+50	1701 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	64	16	35	33 to 36	1	28 to 31	-	-	-
170+00	1643 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	64	19	35	33 to 36	1	28 to 31	-	-	-
170+50	1635 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	65	22	35	33 to 36	1	27 to 30	-	-	-
171+00	1633 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	65	24	35	33 to 36	1	27 to 30	-	-	-
171+50	1625 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	65	26	35	33 to 36	1	27 to 30	-	-	-
172+00	1623 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	28	35	33 to 36	1	27 to 30	-	-	-
172+50	1619 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	30	35	33 to 36	1	27 to 30	-	-	-
172+50	1615 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	30	35	33 to 36	1	27 to 30	-	-	-
173+00	1609 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	67	32	35	32 to 35	-	-	-	-	-
177+50	1517 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	64	35	30 to 33	-	-	-	-	-
177+50	1515 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	64	35	30 to 33	-	-	-	-	-
178+00	1509 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	66	35	30 to 33	-	-	-	-	-

Civil-Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA Criteria (dBA)	GBN Range Without Mitigation (dBA)	# of Impacts Without Mitigation	GBN with HRDF (dBA)	GBN with RSF (dBA)	GBN with IST (dBA)	GBN with FST (dBA)
178+50	1505 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	68	35	30 to 33	-	-	-	-	-
179+00	1501 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	69	35	30 to 33	-	-	-	-	-
179+50	1421 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	70	35	30 to 33	-	-	-	-	-
179+50	1417 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	70	35	30 to 33	-	-	-	-	-
180+00	1415 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	72	35	30 to 33	-	-	-	-	-
180+50	1409 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	72	35	30 to 33	-	-	-	-	-
181+50	1407 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	72	35	30 to 33	-	-	-	-	-
181+50	1321 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	72	35	30 to 33	-	-	-	-	-
182+00	1317 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	68	82	35	29 to 32	-	-	-	-	-
182+50	1315 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	82	35	29 to 32	-	-	-	-	-
183+00	1309 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	63	82	35	30 to 33	-	-	-	-	-
183+50	1305 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	59	81	35	30 to 33	-	-	-	-	-
183+50	1301 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	54	81	35	30 to 33	-	-	-	-	-
185+50	3215 FRONT ST, ALHAMBRA CA	Residential 1 Unit	45	38	80	35	34 to 37	1	28 to 31	-	-	-
232+50	625 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	34	69	35	34 to 37	3	28 to 31	-	-	-
233+00	621 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	34	70	35	34 to 37	3	28 to 31	-	-	-
234+50	609 S FREMONT AVE, ALHAMBRA, CA	Residential 5+ Units	45	27	71	35	40 to 43	6	34 to 37	30 to 33	-	-
237+00	2605 COMMONWEALTH AVE, ALHAMBRA CA	Residential 2-4 Units	45	52	72	35	42 to 45	3	36 to 39	33 to 36	31 to 34	-
237+50	521 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	73	35	42 to 45	2	36 to 39	32 to 35	-	-
238+00	517 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	74	35	42 to 45	1	36 to 39	32 to 35	-	-
238+50	515 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	76	35	41 to 44	1	35 to 38	32 to 35	-	-
238+00	516 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	22	74	35	45 to 48	2	39 to 42	35 to 38	33 to 36	27 to 30
238+50	509 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	60	76	35	40 to 43	1	34 to 37	31 to 34	-	-
238+50	125 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	22	76	35	44 to 47	2	38 to 41	35 to 38	33 to 36	27 to 30
239+00	505 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	77	35	41 to 44	2	35 to 38	31 to 34	-	-
239+00	504 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	24	77	35	44 to 47	3	38 to 41	34 to 37	32 to 35	-
239+50	503 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	78	35	41 to 44	1	35 to 38	31 to 34	-	-
239+50	500 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	29	78	35	43 to 46	3	37 to 40	33 to 36	31 to 34	-

Civil-Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA Criteria (dBA)	GBN Range Without Mitigation (dBA)	# of Impacts Without Mitigation	GBN with HRDF (dBA)	GBN with RSF (dBA)	GBN with IST (dBA)	GBN with FST (dBA)
240+50	433 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	80	35	40 to 43	1	34 to 37	31 to 34	-	-
240+50	438 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	29	80	35	43 to 46	3	37 to 40	33 to 36	31 to 34	-
241+00	429 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	81	35	40 to 43	1	34 to 37	30 to 33	-	-
241+50	425 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	81	35	34 to 37	1	28 to 31	-	-	-
241+00	430 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	24	81	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
242+00	421 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	82	35	40 to 43	2	34 to 37	30 to 33	-	-
241+50	426 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	20	81	35	43 to 46	2	37 to 40	33 to 36	31 to 34	-
242+00	417 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	50	82	35	40 to 43	1	34 to 37	30 to 33	-	-
242+00	422 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	19	82	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
242+50	415 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	82	35	40 to 43	1	34 to 37	30 to 33	-	-
242+00	418 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	23	82	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
242+50	414 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	16	82	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
243+00	411 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	82	35	40 to 43	1	34 to 37	30 to 33	-	-
243+00	410 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	22	82	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
244+00	405 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	81	35	40 to 43	1	34 to 37	30 to 33	-	-
243+50	406 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	28	81	35	42 to 45	1	36 to 39	33 to 36	31 to 34	-
244+50	401 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	81	35	40 to 43	1	34 to 37	31 to 34	-	-
244+00	402 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	22	81	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
245+00	329 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	80	35	35 to 38	1	29 to 32	-	-	-
244+00	340 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	18	81	35	43 to 46	2	37 to 40	33 to 36	31 to 34	-
244+50	328 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	18	81	35	43 to 46	2	37 to 40	33 to 36	31 to 34	-
245+50	325 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	80	35	41 to 44	1	35 to 38	31 to 34	-	-
245+00	326 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	17	80	35	44 to 47	1	37 to 40	34 to 37	32 to 35	-
246+00	321 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	79	35	41 to 44	1	35 to 38	31 to 34	-	-
245+50	322 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	18	80	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-
246+50	317 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	79	35	41 to 44	1	35 to 38	31 to 34	-	-
247+00	315 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	78	35	41 to 44	1	35 to 38	31 to 34	-	-
246+00	320 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	19	79	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-

Civil-Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA Criteria (dBA)	GBN Range Without Mitigation (dBA)	# of Impacts Without Mitigation	GBN with HRDF (dBA)	GBN with RSF (dBA)	GBN with IST (dBA)	GBN with FST (dBA)
246+50	316 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	18	79	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-
247+50	309 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	77	35	41 to 44	1	35 to 38	31 to 34	-	-
247+00	312 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	20	78	35	44 to 47	2	38 to 41	34 to 37	32 to 35	-
247+50	305 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	77	35	41 to 44	1	35 to 38	31 to 34	-	-
247+50	308 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	19	77	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-
248+00	301 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	49	77	35	42 to 45	1	36 to 39	32 to 35	-	-
248+00	304 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	18	77	35	44 to 47	3	38 to 41	35 to 38	33 to 36	26 to 29
250+00	230 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	29	75	35	44 to 47	4	38 to 41	34 to 37	32 to 35	-
250+50	229 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	75	35	42 to 45	1	36 to 39	32 to 35	-	-
250+00	224 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	28	75	35	44 to 47	3	38 to 41	34 to 37	32 to 35	-
251+00	225 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	51	75	35	42 to 45	2	36 to 39	32 to 35	-	-
250+50	220 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	27	75	35	44 to 47	2	38 to 41	34 to 37	32 to 35	-
251+50	221 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	74	35	42 to 45	1	36 to 39	32 to 35	-	-
251+00	216 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	38	75	35	43 to 46	2	37 to 40	33 to 36	31 to 34	-
251+50	217 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	74	35	42 to 45	1	36 to 39	32 to 35	-	-
252+00	212 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	30	74	35	44 to 47	2	38 to 41	34 to 37	32 to 35	-
252+00	215 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	74	35	42 to 45	1	36 to 39	32 to 35	-	-
252+00	208 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	30	74	35	44 to 47	2	38 to 41	34 to 37	32 to 35	-
253+00	209 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	73	35	42 to 45	1	36 to 39	32 to 35	-	-
253+00	204 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	30	73	35	45 to 48	1	38 to 41	35 to 38	33 to 36	27 to 30
253+50	205 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	73	35	42 to 45	2	36 to 39	32 to 35	-	-
253+00	200 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	33	73	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-
254+00	201 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	72	35	42 to 45	1	36 to 39	33 to 36	31 to 34	-
253+50	128 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	32	73	35	44 to 47	1	38 to 41	35 to 38	33 to 36	27 to 30
254+50	129 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	50	72	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
254+00	126 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	35	72	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-
254+50	125 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	49	72	35	43 to 46	2	37 to 40	33 to 36	31 to 34	-
255+00	120 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	36	72	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-

Civil-Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA Criteria (dBA)	GBN Range Without Mitigation (dBA)	# of Impacts Without Mitigation	GBN with HRDF (dBA)	GBN with RSF (dBA)	GBN with IST (dBA)	GBN with FST (dBA)
255+00	121 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	72	35	42 to 45	1	36 to 39	33 to 36	31 to 34	-
255+50	116 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	31	72	35	45 to 48	1	39 to 42	35 to 38	33 to 36	27 to 30
256+00	117 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	72	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
255+50	112 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	33	72	35	45 to 48	1	38 to 41	35 to 38	33 to 36	27 to 30
256+50	115 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	71	35	43 to 46	2	36 to 39	33 to 36	31 to 34	-
256+00	110 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	35	72	35	44 to 47	1	38 to 41	35 to 38	33 to 36	27 to 30
257+00	109 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	71	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
256+50	104 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	37	71	35	44 to 47	3	38 to 41	34 to 37	32 to 35	-
257+50	105 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	50	71	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
257+00	100 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	31	71	35	45 to 48	1	39 to 42	35 to 38	33 to 36	27 to 30
257+50	101 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	71	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
258+00	34 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	28	71	35	45 to 48	2	39 to 42	35 to 38	33 to 36	28 to 31
258+00	23 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	71	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
258+50	28 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	30	70	35	45 to 48	3	39 to 42	35 to 38	33 to 36	28 to 31
259+00	21 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	70	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
259+00	26 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	29	70	35	45 to 48	1	39 to 42	36 to 39	34 to 37	28 to 31
259+00	19 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	70	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
259+50	22 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	32	70	35	45 to 48	1	39 to 42	35 to 38	33 to 36	28 to 31
260+00	17 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	70	35	43 to 46	1	37 to 40	33 to 36	31 to 34	-
259+50	18 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	31	70	35	45 to 48	3	39 to 42	35 to 38	33 to 36	28 to 31
260+50	15 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	32	70	35	45 to 48	3	39 to 42	35 to 38	33 to 36	28 to 31
267+00	55 N FREMONT AVE, ALHAMBRA, CA	Residential 5+ Units	45	25	73	35	45 to 48	8	39 to 42	35 to 38	33 to 36	26 to 29
265+50	14 N FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	10	71	35	47 to 50	1	40 to 43	37 to 40	35 to 38	29 to 32
265+50	2526 GRAND AVE, ALHAMBRA CA	Residential 5+ Units	45	10	71	35	47 to 50	5	40 to 43	36 to 39	34 to 37	27 to 30
269+00	2601 GRAND AVE, ALHAMBRA CA	Residential 2-4 Units	45	19	74	35	45 to 48	2	39 to 42	35 to 38	33 to 36	27 to 30
267+50	100 N FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	13	73	35	46 to 49	4	39 to 42	36 to 39	34 to 37	27 to 30
271+00	2600 BIRCH ST, ALHAMBRA CA	Residential 2-4 Units	45	19	76	35	45 to 48	2	39 to 42	35 to 38	33 to 36	27 to 30
269+00	2526 BIRCH ST, ALHAMBRA CA	Residential 5+ Units	45	14	74	35	45 to 48	6	39 to 42	35 to 38	33 to 36	26 to 29

Civil-Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA Criteria (dBA)	GBN Range Without Mitigation (dBA)	# of Impacts Without Mitigation	GBN with HRDF (dBA)	GBN with RSF (dBA)	GBN with IST (dBA)	GBN with FST (dBA)
271+50	2601 BIRCH ST, ALHAMBRA CA	Residential 1 Unit	45	17	76	35	45 to 48	1	39 to 42	35 to 38	33 to 36	27 to 30
271+50	2525 BIRCH ST, ALHAMBRA CA	Residential 1 Unit	45	11	76	35	45 to 48	1	39 to 42	35 to 38	33 to 36	27 to 30
273+00	209 N FREMONT AVE, ALHAMBRA CA	Residential 1 Unit	45	18	77	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-
272+50	208 N FREMONT AVE, ALHAMBRA CA	Residential 2-4 Units	45	23	76	35	44 to 47	2	38 to 41	34 to 37	32 to 35	-
273+00	211 N FREMONT AVE, ALHAMBRA CA	Residential 1 Unit	45	21	77	35	44 to 47	1	38 to 41	34 to 37	32 to 35	-
273+00	212 N FREMONT AVE, ALHAMBRA CA	Residential 2-4 Units	45	19	77	35	44 to 47	3	38 to 41	34 to 37	32 to 35	-
274+00	215 N FREMONT AVE, ALHAMBRA CA	Residential 2-4 Units	45	19	77	35	44 to 47	2	38 to 41	34 to 37	32 to 35	-
276+00	2067 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	51	78	35	32 to 35	-	-	-	-	-
275+50	2070 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	78	35	32 to 35	-	-	-	-	-
277+00	2061 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	51	79	35	32 to 35	-	-	-	-	-
276+00	2064 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	78	35	32 to 35	-	-	-	-	-
277+50	2057 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	79	35	32 to 35	-	-	-	-	-
277+00	2060 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	52	79	35	32 to 35	-	-	-	-	-
278+00	2055 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	47	79	35	32 to 35	-	-	-	-	-
277+50	2054 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	52	79	35	32 to 35	-	-	-	-	-
278+00	2050 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	54	79	35	31 to 34	-	-	-	-	-
278+50	2051 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	79	35	32 to 35	-	-	-	-	-
278+50	2046 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	59	79	35	31 to 34	-	-	-	-	-
279+50	2045 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	44	80	35	32 to 35	-	-	-	-	-
279+00	2042 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	55	80	35	31 to 34	-	-	-	-	-
279+50	2040 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	90	80	35	27 to 30	-	-	-	-	-
279+50	2035 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	44	80	35	32 to 35	-	-	-	-	-
281+50	2030 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	180	80	35	18 to 21	-	-	-	-	-
280+50	2031 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	44	81	35	32 to 35	-	-	-	-	-
281+00	2027 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	50	81	35	32 to 35	-	-	-	-	-
281+50	2020 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	143	80	35	22 to 25	-	-	-	-	-
282+00	2023 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	66	79	35	30 to 33	-	-	-	-	-
282+50	2016 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	89	78	35	28 to 31	-	-	-	-	-

Civil-Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA Criteria (dBA)	GBN Range Without Mitigation (dBA)	# of Impacts Without Mitigation	GBN with HRDF (dBA)	GBN with RSF (dBA)	GBN with IST (dBA)	GBN with FST (dBA)
282+50	2019 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	51	78	35	32 to 35	-	-	-	-	-
283+00	2012 N FREMONT AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	19	76	35	35 to 38	1	29 to 32	-	-	-
283+00	2015 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	64	76	35	31 to 34	-	-	-	-	-
283+50	2008 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	46	75	35	33 to 36	2	27 to 30	-	-	-
284+00	2004 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	34	74	35	34 to 37	1	28 to 31	-	-	-
284+00	2001 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	100	74	35	27 to 30	-	-	-	-	-
284+50	2000 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	18	71	35	36 to 39	1	30 to 33	-	-	-
285+50	1404 MAPLE ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	68	35	37 to 40	1	32 to 35	-	-	-
286+00	1408 MAPLE ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	68	35	37 to 40	1	32 to 35	-	-	-
286+50	1412 MAPLE ST, SOUTH PASADENA CA	Residential 1 Unit	45	1	70	35	37 to 40	1	31 to 34	-	-	-
287+00	1409 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	72	35	37 to 40	1	31 to 34	-	-	-
287+00	1415 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	72	35	37 to 40	1	31 to 34	-	-	-
288+00	1417 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	74	35	36 to 39	1	31 to 34	-	-	-
289+00	1414 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	4	76	35	36 to 39	1	30 to 33	-	-	-
289+00	1418 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	76	35	36 to 39	1	30 to 33	-	-	-
289+50	1422 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	79	35	35 to 38	1	30 to 33	-	-	-
290+50	1421 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	10	87	35	34 to 37	1	28 to 31	-	-	-
290+50	1425 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	87	35	34 to 37	1	29 to 32	-	-	-
291+00	1429 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	97	35	33 to 36	1	27 to 30	-	-	-
292+50	1428 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	95	35	33 to 36	1	28 to 31	-	-	-
292+50	1432 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	95	35	33 to 36	1	28 to 31	-	-	-
299+50	1801 FAIR OAKS AVE, SOUTH PASADENA CA	Residential Condo	25	72	70	35	34 to 37	21	28 to 31	-	-	-
302+50	1520 SPRUCE ST, SOUTH PASADENA CA	Residential Condo	45	55	71	35	41 to 44	12	35 to 38	35 to 38	29 to 32	-
301+50	1612 SPRUCE ST, SOUTH PASADENA CA	Residential 1 Unit	45	159	71	35	29 to 32	-	-	-	-	-
302+50	1714 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	82	71	35	38 to 41	7	32 to 35	-	-	-
304+00	1715 FAIR OAKS AVE, SOUTH PASADENA CA	Residential Condo	45	67	72	35	39 to 42	15	33 to 36	39 to 42	27 to 30	-
303+00	1700 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	69	72	35	39 to 42	27	33 to 36	33 to 36	27 to 30	-
304+00	1509 LAUREL ST, SOUTH PASADENA CA	Residential 5+ Units	45	69	72	35	39 to 42	15	33 to 36	33 to 36	27 to 30	-

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305+50	1540 LAUREL ST, SOUTH PASADENA CA	Residential 5+ Units	45	66	73	35	40 to 43	16	33 to 36	29 to 32	-	-
307+50	1616 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	68	74	35	39 to 42	19	33 to 36	29 to 32	-	-
307+50	1615 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	78	74	35	38 to 41	4	32 to 35	-	-	-
307+50	1609 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	69	74	35	39 to 42	12	33 to 36	29 to 32	-	-
308+50	1612 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	73	74	35	39 to 42	14	33 to 36	29 to 32	-	-
308+50	1515 OAK ST, SOUTH PASADENA CA	Residential Condo	45	68	74	35	39 to 42	14	33 to 36	29 to 32	-	-
309+50	1600 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	89	75	35	37 to 40	4	31 to 34	-	-	-
312+50	1509 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	83	74	35	37 to 40	16	31 to 34	-	-	-
312+50	1505 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	63	74	35	40 to 43	12	34 to 37	30 to 33	-	-
313+50	1500 FAIR OAKS AVE, SOUTH PASADENA CA SOUTH PASADENA MIDDLE SCHOOL	Institutional	45	71	74	40	32 to 35	-	-	-	-	-
314+50	1425 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	70	73	35	39 to 42	2	33 to 36	29 to 32	-	-
315+00	1421 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	70	73	35	39 to 42	2	33 to 36	29 to 32	-	-
315+50	1415 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	71	73	35	39 to 42	2	33 to 36	29 to 32	-	-
316+00	1411 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	69	73	35	39 to 42	5	33 to 36	29 to 32	-	-
316+00	1407 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 1 Unit	45	72	73	35	39 to 42	1	33 to 36	29 to 32	-	-
327+50	1118 FAIR OAKS AVE, SOUTH PASADENA CA HAPPY FEET MASSAGE	Quiet Office	45	32	71	40	44 to 47	1	38 to 41	34 to 37	-	-
352+00	513 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	28	93	35	33 to 36	12	27 to 30	-	-	-
352+50	509 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	30	93	35	32 to 35	-	-	-	-	-
353+00	505 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	28	93	35	33 to 36	12	27 to 30	-	-	-
353+50	501 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	55	53	93	35	32 to 35	-	-	-	-	-
355+00	435 FAIR OAKS AVE, SOUTH PASADENA CA WAR MEMORIAL PARK & BUILDING	Institutional	55	27	94	40	29 to 32	-	-	-	-	-
358+50	1681 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	79	94	35	28 to 31	-	-	-	-	-
361+00	1675 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	57	95	35	30 to 33	-	-	-	-	-
363+00	1653 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	48	96	35	31 to 34	-	-	-	-	-
364+50	1645 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	50	96	35	31 to 34	-	-	-	-	-
365+50	234 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	46	96	35	31 to 34	-	-	-	-	-
365+50	230 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	46	96	35	31 to 34	-	-	-	-	-

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366+50	226 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	47	97	35	31 to 34	-	-	-	-	-
368+50	1609 RAYMOND HILL RD, SOUTH PASADENA CA	Residential 2-4 Units	55	22	102	35	32 to 35	-	-	-	-	-
369+00	1602 RAYMOND HILL RD, SOUTH PASADENA CA	Residential 2-4 Units	55	30	104	35	31 to 34	-	-	-	-	-
371+50	1231 COLUMBIA PL, PASADENA CA	Residential 2-4 Units	55	143	98	35	22 to 25	-	-	-	-	-
372+00	1223 COLUMBIA PL, PASADENA CA	Residential 2-4 Units	55	126	79	35	25 to 28	-	-	-	-	-
372+50	1215 COLUMBIA PL, PASADENA CA	Residential 1 Unit	55	110	81	35	27 to 30	-	-	-	-	-
374+00	20 W STATE ST, PASADENA, CA	Residential 2-4 Units	55	65	98	35	30 to 33	-	-	-	-	-
391+00	950 RAYMOND AVE, PASADENA CA ART CENTER COLLEGE OF DESIGN	Institutional	35	98	75	40	33 to 36	-	-	-	-	-

Highlighted cells indicate that vibration impacts would remain for that level of mitigation.

The groundborne noise impacts due to LRT operation and by type of land use are summarized in Table 5-2. Evaluation of the groundborne noise predictions indicates that four hundred and fifty-four (454) residential buildings and one (1) commercial office building would be impacted without mitigation. With the mitigation determined from the analysis, all groundborne noise impacts would be eliminated as indicated in Table 5-1and discussed in Section 5.1.2 below.

Table 5-2 Summary of LRT Groundborne Noise Impacts by Land Use

Land Use Category	Type of Use	Building Details	Number of Buildings Impacted
Category 2	Residence	Single Family (detached)	93
		Single-family (condominium)	62
		Multi-family (2 to 4 units)	107
		Multi-family (5 units and greater)	192
Category 3	Commercial	Quiet Office	1

The projected levels of the groundborne vibration for the LRT tunnel alignment are shown in Table 5-3. The predicted groundborne vibration levels are compared to the appropriate FTA criteria. Evaluation of the vibration predictions indicates that no sensitive receivers would be impacted by groundborne vibration due to LRT operations.

Table 5-3 Groundborne Vibration Impacts for LRT Tunnel Alignment

Key: GBV = Groundborne vibration

Civil Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA GBV Criteria (VdB)	GBV Range Without Mitigation (VdB)	# of Impacts Without Mitigation
167+00	1809 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	201	0	72	47 to 50	-
167+00	1805 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	149	0	72	49 to 52	-
167+00	1801 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	126	0	72	50 to 53	-
167+00	1725 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	133	0	72	50 to 53	-
167+00	1721 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	130	0	72	50 to 53	-
167+50	1717 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	130	0	72	50 to 53	-
168+50	1715 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	63	9	72	58 to 61	-
168+50	1709 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	63	9	72	58 to 61	-
169+00	1705 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	64	13	72	58 to 61	-
169+50	1701 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	64	16	72	58 to 61	-
170+00	1643 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	64	19	72	58 to 61	-
170+50	1635 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	65	22	72	57 to 60	-
171+00	1633 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	65	24	72	57 to 60	-
171+50	1625 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	65	26	72	57 to 60	-
172+00	1623 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	28	72	57 to 60	-
172+50	1619 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	30	72	57 to 60	-
172+50	1615 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	30	72	56 to 59	-

Civil Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA GBV Criteria (VdB)	GBV Range Without Mitigation (VdB)	# of Impacts Without Mitigation
173+00	1609 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	67	32	72	56 to 59	-
177+50	1517 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	64	72	53 to 56	-
177+50	1515 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	64	72	53 to 56	-
178+00	1509 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	66	72	53 to 56	-
178+50	1505 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	68	72	53 to 56	-
179+00	1501 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	69	72	52 to 55	-
179+50	1421 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	70	72	52 to 55	-
179+50	1417 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	70	72	52 to 55	-
180+00	1415 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	72	72	52 to 55	-
180+50	1409 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	72	72	52 to 55	-
181+50	1407 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	70	72	72	52 to 55	-
181+50	1321 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	69	72	72	52 to 55	-
182+00	1317 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	68	82	72	51 to 54	-
182+50	1315 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	66	82	72	51 to 54	-
183+00	1309 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	63	82	72	52 to 55	-
183+50	1305 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	59	81	72	52 to 55	-
183+50	1301 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	35	54	81	72	52 to 55	-
185+50	3215 FRONT ST, ALHAMBRA CA	Residential 1 Unit	45	38	80	72	55 to 58	-
232+50	625 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	34	69	72	55 to 58	-
233+00	621 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	34	70	72	55 to 58	-
234+50	609 S FREMONT AVE, ALHAMBRA, CA	Residential 5+ Units	45	27	71	72	56 to 59	-
237+00	2605 COMMONWEALTH AVE, ALHAMBRA CA	Residential 2-4 Units	45	52	72	72	62 to 65	-
237+50	521 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	73	72	62 to 65	-
238+00	517 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	74	72	61 to 64	-
238+50	515 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	76	72	61 to 64	-
238+00	516 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	22	74	72	64 to 67	-
238+50	509 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	60	76	72	60 to 63	-
238+50	125 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	22	76	72	63 to 66	-
239+00	505 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	77	72	60 to 63	-
239+00	504 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	24	77	72	63 to 66	-
239+50	503 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	78	72	60 to 63	-
239+50	500 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	29	78	72	62 to 65	-
240+50	433 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	80	72	60 to 63	-
240+50	438 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	29	80	72	61 to 64	-
241+00	429 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	81	72	59 to 62	-
241+50	425 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	81	72	57 to 60	-
241+00	430 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	24	81	72	61 to 64	-
242+00	421 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	82	72	59 to 62	-
241+50	426 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	20	81	72	61 to 64	-
242+00	417 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	50	82	72	59 to 62	-

Civil Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA GBV Criteria (VdB)	GBV Range Without Mitigation (VdB)	# of Impacts Without Mitigation
242+00	422 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	19	82	72	61 to 64	-
242+50	415 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	82	72	59 to 62	-
242+00	418 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	23	82	72	61 to 64	-
242+50	414 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	16	82	72	61 to 64	-
243+00	411 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	82	72	59 to 62	-
243+00	410 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	22	82	72	61 to 64	-
244+00	405 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	81	72	59 to 62	-
243+50	406 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	28	81	72	61 to 64	-
244+50	401 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	81	72	60 to 63	-
244+00	402 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	22	81	72	61 to 64	-
245+00	329 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	80	72	57 to 60	-
244+00	340 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	18	81	72	61 to 64	-
244+50	328 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	18	81	72	62 to 65	-
245+50	325 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	80	72	60 to 63	-
245+00	326 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	17	80	72	62 to 65	-
246+00	321 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	79	72	60 to 63	-
245+50	322 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	18	80	72	62 to 65	-
246+50	317 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	79	72	60 to 63	-
247+00	315 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	78	72	60 to 63	-
246+00	320 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	19	79	72	62 to 65	-
246+50	316 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	18	79	72	62 to 65	-
247+50	309 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	77	72	61 to 64	-
247+00	312 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	20	78	72	62 to 65	-
247+50	305 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	77	72	60 to 63	-
247+50	308 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	19	77	72	63 to 66	-
248+00	301 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	49	77	72	61 to 64	-
248+00	304 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	18	77	72	63 to 66	-
250+00	230 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	29	75	72	63 to 66	-
250+50	229 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	75	72	61 to 64	-
250+00	224 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	28	75	72	63 to 66	-
251+00	225 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	51	75	72	61 to 64	-
250+50	220 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	27	75	72	63 to 66	-
251+50	221 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	52	74	72	61 to 64	-
251+00	216 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	38	75	72	62 to 65	-
251+50	217 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	74	72	61 to 64	-
252+00	212 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	30	74	72	63 to 66	-
252+00	215 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	53	74	72	61 to 64	-
252+00	208 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	30	74	72	63 to 66	-
253+00	209 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	73	72	62 to 65	-
253+00	204 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	30	73	72	64 to 67	-

Civil Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA GBV Criteria (VdB)	GBV Range Without Mitigation (VdB)	# of Impacts Without Mitigation
253+50	205 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	73	72	62 to 65	-
253+00	200 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	33	73	72	63 to 66	-
254+00	201 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	72	72	62 to 65	-
253+50	128 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	32	73	72	64 to 67	-
254+50	129 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	50	72	72	62 to 65	-
254+00	126 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	35	72	72	63 to 66	-
254+50	125 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	49	72	72	62 to 65	-
255+00	120 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	36	72	72	63 to 66	-
255+00	121 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	72	72	62 to 65	-
255+50	116 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	31	72	72	64 to 67	-
256+00	117 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	72	72	62 to 65	-
255+50	112 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	33	72	72	64 to 67	-
256+50	115 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	52	71	72	62 to 65	-
256+00	110 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	35	72	72	64 to 67	-
257+00	109 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	51	71	72	62 to 65	-
256+50	104 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	37	71	72	64 to 67	-
257+50	105 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	50	71	72	63 to 66	-
257+00	100 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	31	71	72	64 to 67	-
257+50	101 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	71	72	63 to 66	-
258+00	34 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	28	71	72	64 to 67	-
258+00	23 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	71	72	63 to 66	-
258+50	28 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	30	70	72	64 to 67	-
259+00	21 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	70	72	63 to 66	-
259+00	26 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	29	70	72	65 to 68	-
259+00	19 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	70	72	63 to 66	-
259+50	22 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	32	70	72	64 to 67	-
260+00	17 S FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	49	70	72	63 to 66	-
259+50	18 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	31	70	72	65 to 68	-
260+50	15 S FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	32	70	72	64 to 67	-
267+00	55 N FREMONT AVE, ALHAMBRA, CA	Residential 5+ Units	45	25	73	72	61 to 64	-
265+50	14 N FREMONT AVE, ALHAMBRA, CA	Residential 1 Unit	45	10	71	72	65 to 68	-
265+50	2526 GRAND AVE, ALHAMBRA CA	Residential 5+ Units	45	10	71	72	63 to 66	-
269+00	2601 GRAND AVE, ALHAMBRA CA	Residential 2-4 Units	45	19	74	72	64 to 67	-
267+50	100 N FREMONT AVE, ALHAMBRA, CA	Residential 2-4 Units	45	13	73	72	62 to 65	-
271+00	2600 BIRCH ST, ALHAMBRA CA	Residential 2-4 Units	45	19	76	72	63 to 66	-
269+00	2526 BIRCH ST, ALHAMBRA CA	Residential 5+ Units	45	14	74	72	62 to 65	-
271+50	2601 BIRCH ST, ALHAMBRA CA	Residential 1 Unit	45	17	76	72	63 to 66	-
271+50	2525 BIRCH ST, ALHAMBRA CA	Residential 1 Unit	45	11	76	72	64 to 67	-
273+00	209 N FREMONT AVE, ALHAMBRA CA	Residential 1 Unit	45	18	77	72	63 to 66	-
272+50	208 N FREMONT AVE, ALHAMBRA CA	Residential 2-4 Units	45	23	76	72	63 to 66	-

Civil Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA GBV Criteria (VdB)	GBV Range Without Mitigation (VdB)	# of Impacts Without Mitigation
273+00	211 N FREMONT AVE, ALHAMBRA CA	Residential 1 Unit	45	21	77	72	63 to 66	-
273+00	212 N FREMONT AVE, ALHAMBRA CA	Residential 2-4 Units	45	19	77	72	63 to 66	-
274+00	215 N FREMONT AVE, ALHAMBRA CA	Residential 2-4 Units	45	19	77	72	63 to 66	-
276+00	2067 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	51	78	72	54 to 57	-
275+50	2070 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	78	72	55 to 58	-
277+00	2061 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	51	79	72	54 to 57	-
276+00	2064 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	78	72	55 to 58	-
277+50	2057 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	79	72	55 to 58	-
277+00	2060 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	52	79	72	54 to 57	-
278+00	2055 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	47	79	72	55 to 58	-
277+50	2054 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	52	79	72	54 to 57	-
278+00	2050 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	54	79	72	54 to 57	-
278+50	2051 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	48	79	72	55 to 58	-
278+50	2046 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	59	79	72	53 to 56	-
279+50	2045 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	44	80	72	55 to 58	-
279+00	2042 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	55	80	72	54 to 57	-
279+50	2040 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	90	80	72	49 to 52	-
279+50	2035 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	44	80	72	55 to 58	-
281+50	2030 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	180	80	72	38 to 41	-
280+50	2031 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	44	81	72	55 to 58	-
281+00	2027 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	50	81	72	54 to 57	-
281+50	2020 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	143	80	72	42 to 45	-
282+00	2023 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	66	79	72	52 to 55	-
282+50	2016 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	89	78	72	49 to 52	-
282+50	2019 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	51	78	72	54 to 57	-
283+00	2012 N FREMONT AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	19	76	72	58 to 61	-
283+00	2015 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	64	76	72	53 to 56	-
283+50	2008 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	46	75	72	55 to 58	-
284+00	2004 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	34	74	72	57 to 60	-
284+00	2001 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	100	74	72	48 to 51	-
284+50	2000 N FREMONT AVE, SOUTH PASADENA CA	Residential 1 Unit	45	18	71	72	59 to 62	-
285+50	1404 MAPLE ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	68	72	61 to 64	-
286+00	1408 MAPLE ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	68	72	61 to 64	-
286+50	1412 MAPLE ST, SOUTH PASADENA CA	Residential 1 Unit	45	1	70	72	60 to 63	-
287+00	1409 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	72	72	60 to 63	-
287+00	1415 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	72	72	60 to 63	-
288+00	1417 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	74	72	60 to 63	-
289+00	1414 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	4	76	72	59 to 62	-
289+00	1418 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	76	72	59 to 62	-
289+50	1422 BEECH ST, SOUTH PASADENA CA	Residential 1 Unit	45	0	79	72	59 to 62	-

Civil Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA GBV Criteria (VdB)	GBV Range Without Mitigation (VdB)	# of Impacts Without Mitigation
290+50	1421 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	10	87	72	57 to 60	-
290+50	1425 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	87	72	58 to 61	-
291+00	1429 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	97	72	56 to 59	-
292+50	1428 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	95	72	57 to 60	-
292+50	1432 ONEONTA KNL, SOUTH PASADENA CA	Residential 1 Unit	45	0	95	72	57 to 60	-
299+50	1801 FAIR OAKS AVE, SOUTH PASADENA CA	Residential Condo	25	72	70	72	48 to 51	-
302+50	1520 SPRUCE ST, SOUTH PASADENA CA	Residential Condo	45	55	71	72	55 to 58	-
301+50	1612 SPRUCE ST, SOUTH PASADENA CA	Residential 1 Unit	45	159	71	72	49 to 52	-
302+50	1714 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	82	71	72	52 to 55	-
304+00	1715 FAIR OAKS AVE, SOUTH PASADENA CA	Residential Condo	45	67	72	72	54 to 57	-
303+00	1700 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	69	72	72	54 to 57	-
304+00	1509 LAUREL ST, SOUTH PASADENA CA	Residential 5+ Units	45	69	72	72	54 to 57	-
305+50	1540 LAUREL ST, SOUTH PASADENA CA	Residential 5+ Units	45	66	73	72	54 to 57	-
307+50	1616 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	68	74	72	54 to 57	-
307+50	1615 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	78	74	72	55 to 58	-
307+50	1609 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	69	74	72	54 to 57	-
308+50	1612 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	73	74	72	53 to 56	-
308+50	1515 OAK ST, SOUTH PASADENA CA	Residential Condo	45	68	74	72	54 to 57	-
309+50	1600 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	89	75	72	52 to 55	-
312+50	1509 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	83	74	72	52 to 55	-
312+50	1505 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	63	74	72	54 to 57	-
313+50	1500 FAIR OAKS AVE, SOUTH PASADENA CA SOUTH PASADENA MIDDLE SCHOOL	Institutional	45	71	74	75	52 to 55	-
314+50	1425 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	70	73	72	55 to 58	-
315+00	1421 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	70	73	72	55 to 58	-
315+50	1415 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	45	71	73	72	55 to 58	-
316+00	1411 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	45	69	73	72	55 to 58	-
316+00	1407 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 1 Unit	45	72	73	72	55 to 58	-
327+50	1118 FAIR OAKS AVE, SOUTH PASADENA CA HAPPY FEET MASSAGE	Quiet Office	45	32	71	75	58 to 61	-
352+00	513 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	28	93	72	53 to 56	-
352+50	509 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	30	93	72	53 to 56	-
353+00	505 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	28	93	72	53 to 56	-
353+50	501 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 2-4 Units	55	53	93	72	54 to 57	-
355+00	435 FAIR OAKS AVE, SOUTH PASADENA CA WAR MEMORIAL PARK & BUILDING	Institutional	55	27	94	75	55 to 58	-
358+50	1681 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	79	94	72	48 to 51	-
361+00	1675 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	57	95	72	50 to 53	-
363+00	1653 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	48	96	72	51 to 54	-
364+50	1645 AMBERWOOD DR, SOUTH PASADENA CA	Residential 5+ Units	55	50	96	72	51 to 54	-
365+50	234 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	46	96	72	51 to 54	-
365+50	230 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	46	96	72	51 to 54	-

Civil Station	Receiver Location	Receiver Type	Design Speed (mph)	Horizontal Distance To Near Track CL (ft)	Rail Depth (ft)	FTA GBV Criteria (VdB)	GBV Range Without Mitigation (VdB)	# of Impacts Without Mitigation
366+50	226 FAIR OAKS AVE, SOUTH PASADENA CA	Residential 5+ Units	55	47	97	72	51 to 54	-
368+50	1609 RAYMOND HILL RD, SOUTH PASADENA CA	Residential 2-4 Units	55	22	102	72	53 to 56	-
369+00	1602 RAYMOND HILL RD, SOUTH PASADENA CA	Residential 2-4 Units	55	30	104	72	52 to 55	-
371+50	1231 COLUMBIA PL, PASADENA CA	Residential 2-4 Units	55	143	98	72	42 to 45	-
372+00	1223 COLUMBIA PL, PASADENA CA	Residential 2-4 Units	55	126	79	72	46 to 49	-
372+50	1215 COLUMBIA PL, PASADENA CA	Residential 1 Unit	55	110	81	72	48 to 51	-
374+00	20 W STATE ST, PASADENA, CA	Residential 2-4 Units	55	65	98	72	52 to 55	-
391+00	950 RAYMOND AVE, PASADENA CA ART CENTER COLLEGE OF DESIGN	Institutional	35	98	75	75	48 to 51	-

5.1.2 Groundborne Noise and Vibration Mitigation

The specific type of mitigation measure appropriate for any particular location is dependent on several factors, including the dynamic characteristics of the transit vehicle and track, soil characteristics, as well as the type and use of the nearby buildings, all of which affect the frequency content of the resultant noise and vibration inside buildings. The LRT tunnel alignment will be a concrete slab track system, and therefore only certain types of vibration isolation systems are applicable.

Groundborne noise reduction is the achieved by vibration isolation of the track from the underlying tunnel structure. The amount of reduction in vibration transmitted to the tunnel structure is the insertion loss (IL) as discussed in Section 4.2. The amount of reduction obtainable is highly frequency dependent and varies depending on the type of vibration isolation measure. Four groundborne noise mitigation measures were evaluated where the results of the prediction model indicate impacts; they were:

- Highly resilient direct fixation (HRDF) fasteners (e.g., Egg Type DF fastener)
- Rail suspension fastener (RSF) system (an example of which is the Panguard fastener)
- Isolated slab track system (IST) – concrete slab poured on top of an continuous elastomeric mat
- Floating slab track system (FST) – concrete slab supported by discrete elastomeric pads

If moderate groundborne noise reduction (i.e., 5 to 7 dBA) is indicated, then a highly resilient direct fixation (HRDF) rail fastener would be adequate. Where more reduction (i.e., up to 10 dBA) is necessary, a so-called rail suspension fastener (RSF) would suffice. If more than 10 dBA of reduction is necessary then either an isolated slab track (IST) system (up to 12 dBA reduction) or even a floating slab track (FST) system (18 dBA or more reduction depending on the design) would be necessary. If properly designed, an FST can result in as much as 25 to 30 dBA of reduction. This is accomplished by tailoring the FST design. (i.e., tuning it) to the specific circumstances. In terms of groundborne noise reduction, the important characteristic of an FST is its natural frequency. For SR710 LRT tunnel alignment, an FST with a natural frequency of 16 Hertz (Hz) appears to be adequate.

It is important to note that where FST is indicated as the mitigation, groundborne noise levels with IST exceed the criterion by only 1 dBA except in four locations. Consequently during engineering for the project, it is reasonable to expect that further field measurements may find that predicted levels are somewhat lower and that it is possible to mitigate these impacts with IST.

Special considerations for mitigating groundborne noise produced by special trackwork (i.e., crossover switch) are necessary where noise and/or vibration impacts occur. Crossovers are large trackwork structures and even though it is just the frog that produces the groundborne noise, the entire crossover needs to have the same mitigation measure (e.g., HRDF, IST). The proper functioning of the crossover also places some restrictions on design of the mitigation measures that can be used.

Figure 5-1, Figure 5-2, Figure 5-3, and Figure 5-4 indicate the location of the mitigation along the LRT tunnel alignment that is indicated by the analysis. The extents of mitigation indicated are only the minimum required to achieve the FTA criteria. Based on the analysis performed for this study specific mitigation measures have been identified as being sufficiently adequate to mitigate all operational groundborne noise impacts. Those mitigation measures are indicated in Table 5-1 and Table 5-4. During the engineering design phase of the project additional field testing and analysis will be conducted to refine the groundborne noise impact predictions and determine specific mitigation measures to be implemented resulting in groundborne noise levels that are in compliance with the FTA criteria.

Figure 5-1 Location of Groundborne Noise Mitigation Measures - Segment 1

Figure 5-2 Location of Groundborne Noise Mitigation Measures - Segment 2

Figure 5-3 Location of Groundborne Noise Mitigation Measures - Segment 3

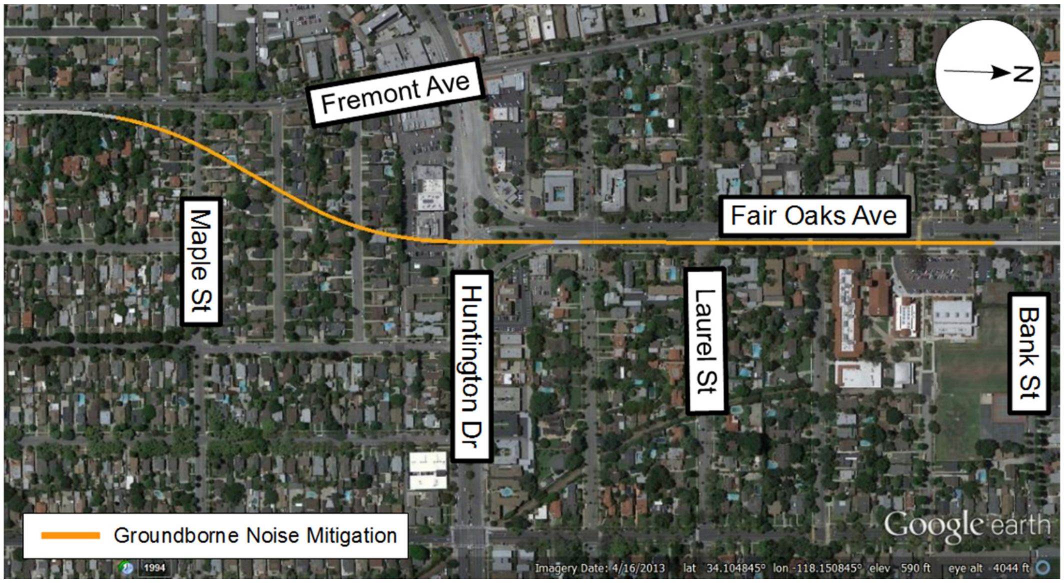

Figure 5-4 Location of Groundborne Noise Mitigation Measures - Segment 4

Table 5-4 summarizes the location (by civil station), the extents and the types of each mitigation measure indicated by the analysis to reduce groundborne noise impacts. In general, for practical reasons of which construction is a major factor, the design of transit track systems dictates a minimum length of track fixation/support structure. Generally track designers use 500 feet as a minimum length of any type of track system when there is more than one system. For other practical reasons, transit agencies and their track designers may also minimize the number of different systems to be installed on a new transit line. For example, the number of track mitigation measures might be reduced to just two (e.g., RSF and FST). This is aside from the standard track fixation system to be used where no mitigation is necessary.

Table 5-4 Summary of Groundborne Noise Mitigation Measures

Area	Alignment Station	Length of Mitigation[1] (ft)	Type of Mitigation[2]
1	168+00 to 173+00	500	HRDF
2	183+00 to 188+00	500	HRDF
3	231+00 to 236+50	500	RSF
4	236+50 to 241+50	500	FST
5	241+50 to 247+50	600	IST
6	247+50 to 274+50	2,700	FST
7	282+50 to 300+00	1,750	HRDF
8	301+00 to 306+00	500	IST
9	306+00 to 316+50	1,050	RSF
10	325+00 to 330+00	500	RSF
11	350+00 to 355+00	500	HRDF

Key:
[1] Mitigation lengths are a minimum of 500 ft and gaps of 500 ft or less are filled in
[2] Mitigation measure applies to both tracks
HRDF = high resilience direct fixation fasteners
RSF = rail suspension fasteners
IST = isolated slab track
FST = floating slab track

In summary, tabulation of the data in Table 5-4 indicates a total of 3,250 tunnel feet (both tracks) of HRDF, 2,050 tunnel feet of RSF, 1,100 tunnel feet of IST, and 3,200 tunnel feet of FST as mitigation for a total of 9,600 tunnel feet of mitigation in the LRT tunnel.

5.2 Freeway Tunnel Alignment

The groundborne noise and vibration impacts along the SR710 Freeway tunnel alignment are evaluated using the same FTA criteria (Ref. 1) as were used for the LRT tunnel alignment. All residential land uses identified along the freeway tunnel alignment were treated individually in the groundborne noise and vibration prediction model. Institutional land uses (e.g., schools) were also treated individually in the calculations.

Although modeled, it is unnecessary to predict groundborne noise for motor vehicles in light of the great depth of the freeway tunnel and the very low levels of vibration generated in the audible frequency range (see **Error! Reference source not found.**). The projected levels of groundborne vibration for heavy motor vehicles travelling within the Freeway tunnel alignment were calculated using the prediction models described in Section 4.2.

The predicted groundborne vibration levels were compared to the FTA criteria. Determination of impact and mitigation measures, where needed and their extents are based on the upper value in each range. The analysis indicates no predicted groundborne vibration impacts for the freeway tunnel alignment according to the FTA vibration criteria.

5.2.1 Groundborne Vibration Impacts

The projected levels of the groundborne vibration for the Freeway tunnel alignment are shown in Table 5-5. The predicted groundborne vibration levels are compared to the appropriate FTA criteria. All of the predicted vibration levels are considerably lower than the appropriate FTA criterion for each receiver. Evaluation of the groundborne vibration from motor vehicles traveling in the Freeway tunnel indicates that no sensitive receivers would be impacted by operational vibration.

Table 5-5 Groundborne Vibration Impacts for Freeway Tunnel Alignment

Key: GBV = Groundborne vibration

Civil-Station	Receiver Location	Receiver Type	Vehicle Speed (mph)	Horizontal Distance To Alignment (ft)	Alignment Depth (ft)	FTA Criteria (VdB)	GBV Range (VdB)	# of Impacts
1439+15	1900 CHARNWOOD AVE, ALHAMBRA CA	Residential 1 Unit	50	115	19	72	53 to 56	-
1440+35	2292 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	158	21	72	50 to 53	-
1441+50	2306 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	160	27	72	50 to 53	-
1441+50	1815 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	140	32	72	50 to 53	-
1442+00	2314 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	151	30	72	50 to 53	-
1442+50	2318 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	144	33	72	50 to 53	-
1443+00	1809 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	143	40	72	49 to 52	-
1443+00	2322 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	140	36	72	50 to 53	-
1443+50	1805 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	135	44	72	49 to 52	-
1443+50	2330 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	138	40	72	50 to 53	-
1444+00	1801 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	127	48	72	49 to 52	-
1444+00	2338 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	144	43	72	49 to 52	-
1444+50	2342 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	148	47	72	48 to 51	-
1444+50	1725 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	120	52	72	49 to 52	-
1445+00	1721 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	115	56	72	49 to 52	-
1445+50	1717 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	110	59	72	49 to 52	-
1445+50	2350 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	155	55	72	47 to 50	-
1446+70	1709 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	86	41	72	53 to 56	-
1446+75	2354 HIGHBURY AVE, LOS ANGELES CA	Residential 1 Unit	50	164	22	72	50 to 53	-
1447+00	1643 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	86	42	72	53 to 56	-
1447+50	1635 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	87	44	72	53 to 56	-
1448+50	1633 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	90	48	72	52 to 55	-
1449+00	1623 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	94	49	72	52 to 55	-
1449+50	1619 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	96	49	72	52 to 55	-
1450+00	1615 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	98	50	72	51 to 54	-
1450+50	1609 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	100	51	72	51 to 54	-
1455+00	1515 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	123	91	72	45 to 48	-
1455+50	1509 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	125	92	72	45 to 48	-
1456+00	1501 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	129	94	72	44 to 47	-
1456+50	1421 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	131	97	72	44 to 47	-
1457+00	1417 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	132	99	72	44 to 47	-
1457+50	1415 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	134	101	72	43 to 46	-
1501+50	1315 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	143	108	72	42 to 45	-
1502+00	1305 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	147	112	72	42 to 45	-
1502+50	1301 WESTMONT DR, ALHAMBRA CA	Residential 1 Unit	50	149	115	72	41 to 44	-
1503+50	3215 FRONT ST, ALHAMBRA CA	Residential 1 Unit	50	152	122	72	40 to 43	-
1513+00	3224 MIDVALE PL, ALHAMBRA CA	Residential 1 Unit	50	186	150	72	41 to 44	-

Civil-Station	Receiver Location	Receiver Type	Vehicle Speed (mph)	Horizontal Distance To Alignment (ft)	Alignment Depth (ft)	FTA Criteria (VdB)	GBV Range (VdB)	# of Impacts
1513+00	5548/5550 CONCORD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	150	72	39 to 42	-
1514+50	5528 ALLAN ST, LOS ANGELES CA	Residential 1 Unit	50	0	170	72	36 to 39	-
1515+50	5531 ALLAN ST, LOS ANGELES CA	Residential 1 Unit	50	0	175	72	36 to 39	-
1517+00	3115 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	177	72	36 to 39	-
1517+50	3119 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	178	72	35 to 38	-
1517+50	3123 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	178	72	35 to 38	-
1518+50	3127 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	179	72	35 to 38	-
1519+00	3131 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	180	72	35 to 38	-
1519+50	3135 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	180	72	35 to 38	-
1520+00	3137 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	180	72	35 to 38	-
1520+00	3145 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	180	72	35 to 38	-
1520+50	3201 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	180	72	35 to 38	-
1521+00	3205 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	179	72	35 to 38	-
1521+50	3209 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	180	72	35 to 38	-
1522+00	3215 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	181	72	35 to 38	-
1522+50	32?? SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	182	72	35 to 38	-
1523+00	3223 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	182	72	35 to 38	-
1523+00	3227 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	182	72	35 to 38	-
1523+50	5522 NORWICH AVE, LOS ANGELES CA	Residential 1 Unit	50	0	183	72	35 to 38	-
1526+50	5523 NORWICH AVE, LOS ANGELES CA	Residential 1 Unit	50	0	185	72	35 to 38	-
1527+00	3319 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	185	72	35 to 38	-
1527+50	3323 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	185	72	35 to 38	-
1528+00	3327 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	185	72	35 to 38	-
1528+50	3331 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	186	72	35 to 38	-
1528+50	3335 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	186	72	35 to 38	-
1529+00	3339 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	186	72	35 to 38	-
1529+50	3343 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	186	72	35 to 38	-
1530+00	3401 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	186	72	35 to 38	-
1530+50	3405 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	187	72	34 to 37	-
1531+00	3415 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	187	72	34 to 37	-
1531+50	3419 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	188	72	34 to 37	-
1532+00	3423 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	188	72	34 to 37	-
1532+50	3427 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	188	72	34 to 37	-
1533+00	3431 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	188	72	34 to 37	-
1534+00	5522 TEMPLETON ST, LOS ANGELES CA	Residential 1 Unit	50	0	189	72	34 to 37	-
1536+00	5523 TEMPLETON ST, LOS ANGELES CA	Residential 1 Unit	50	0	190	72	39 to 42	-
1536+50	3515 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	191	72	39 to 42	-
1537+00	3519 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	191	72	39 to 42	-
1537+50	3523 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	192	72	39 to 42	-
1538+00	3529 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	192	72	39 to 42	-
1538+00	3533 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	192	72	39 to 42	-

Civil-Station	Receiver Location	Receiver Type	Vehicle Speed (mph)	Horizontal Distance To Alignment (ft)	Alignment Depth (ft)	FTA Criteria (VdB)	GBV Range (VdB)	# of Impacts
1538+50	3537 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	192	72	39 to 42	-
1539+00	3541 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	192	72	39 to 42	-
1539+50	3701 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	193	72	39 to 42	-
1540+00	3705 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	193	72	39 to 42	-
1540+50	3711 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	194	72	39 to 42	-
1541+00	3715 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	194	72	39 to 42	-
1541+50	3719 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	195	72	38 to 41	-
1542+00	3723 SHEFFIELD AVE, LOS ANGELES CA	Residential 1 Unit	50	0	195	72	38 to 41	-
1542+50	5518 POPLAR BLVD, LOS ANGELES CA	Residential 1 Unit	50	0	197	72	38 to 41	-
1553+50	5465 KEATS ST, LOS ANGELES CA	Residential 1 Unit	50	0	187	72	39 to 42	-
1554+50	5450 SHELLEY ST, LOS ANGELES CA	Residential 1 Unit	50	0	172	72	41 to 44	-
1557+00	5459/5461 SHELLEY ST, LOS ANGELES CA	Residential 1 Unit	50	0	182	72	40 to 43	-
1559+00	5480 S HUNTINGTON DR, LOS ANGELES CA PLAZA DE LA RAZA CHILD DEVELOPMENT SERVICES	Institutional	50	0	181	75	40 to 43	-
1560+00	5457 HUNTINGTON DR N, LOS ANGELES CA	Residential 2-4 Unit	50	0	175	72	40 to 43	-
1560+50	4210 LOWELL AVE, LOS ANGELES CA	Residential 5+ Units	50	26	175	72	42 to 45	-
1562+50	4225 MAYCREST AVE, LOS ANGELES CA	Residential 2-4 Unit	50	0	172	72	41 to 44	-
1564+00	4309 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	172	72	41 to 44	-
1564+50	4306 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	173	72	41 to 44	-
1565+50	4323 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	176	72	40 to 43	-
1566+50	4333 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	179	72	40 to 43	-
1567+00	4338 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	179	72	40 to 43	-
1567+50	4343 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	181	72	40 to 43	-
1568+00	4349 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	183	72	40 to 43	-
1568+50	4352 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	184	72	39 to 42	-
1570+50	4400 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	185	72	39 to 42	-
1571+00	4412 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	186	72	38 to 41	-
1572+00	4416 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	188	72	38 to 41	-
1573+00	4426 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	188	72	38 to 41	-
1574+00	4436 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	189	72	38 to 41	-
1575+00	4441 ALPHA ST, LOS ANGELES CA	Residential 1 Unit	50	0	188	72	38 to 41	-
1575+50	4447 ALPHA ST, LOS ANGELES CA	Residential 1 Unit	50	0	189	72	38 to 41	-
1576+00	4512 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	189	72	38 to 41	-
1576+50	4501 ALPHA ST, LOS ANGELES CA	Residential 1 Unit	50	0	190	72	38 to 41	-
1577+00	4522 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	190	72	38 to 41	-
1577+50	4511 ALPHA ST, LOS ANGELES CA	Residential 1 Unit	50	0	191	72	38 to 41	-
1578+00	4517 ALPHA ST, LOS ANGELES CA	Residential 1 Unit	50	0	191	72	38 to 41	-
1578+50	4536 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	192	72	38 to 41	-
1579+00	4542 MAYCREST AVE, LOS ANGELES CA	Residential 1 Unit	50	0	192	72	38 to 41	-
1580+00	2049 ALPHA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	193	72	38 to 41	-
1580+50	2043 ALPHA ST, SOUTH PASADENA CA	Residential 2-4 Unit	50	0	194	72	37 to 40	-

Civil-Station	Receiver Location	Receiver Type	Vehicle Speed (mph)	Horizontal Distance To Alignment (ft)	Alignment Depth (ft)	FTA Criteria (VdB)	GBV Range (VdB)	# of Impacts
1581+00	2041 ALPHA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	194	72	37 to 40	-
1581+50	2037 ALPHA ST, SOUTH PASADENA CA	Residential 2-4 Unit	50	0	196	72	37 to 40	-
1582+00	2033 ALPHA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	198	72	37 to 40	-
1582+50	2029 ALPHA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	200	72	37 to 40	-
1624+00	925 LYNDON ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	193	72	38 to 41	-
1625+50	914 LYNDON ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	198	72	37 to 40	-
1627+00	915 MONTEREY RD, SOUTH PASADENA CA	Residential 1 Unit	50	0	197	72	37 to 40	-
1629+00	920 MONTEREY RD, SOUTH PASADENA CA	Residential 1 Unit	50	0	196	72	36 to 39	-
1630+50	1133 MERIDIAN AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	196	72	36 to 39	-
1631+00	1131 MERIDIAN AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	194	72	36 to 39	-
1631+50	1130 MERIDIAN AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	195	72	36 to 39	-
1632+00	1122 MERIDIAN AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	195	72	36 to 39	-
1632+50	1119 MERIDIAN AVE, SO PASADENA CA	Residential 1 Unit	50	0	194	72	36 to 39	-
1633+00	1120 MERIDIAN AVE, SOUTH PASADENA CA	Residential 2-4 Unit	50	0	193	72	37 to 40	-
1633+50	1114 MERIDIAN AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	194	72	36 to 39	-
1634+00	1106 MERIDIAN AVE, SOUTH PASADENA CA	Residential 2-4 Unit	50	0	194	72	36 to 39	-
1634+50	1100 MERIDIAN AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	194	72	36 to 39	-
1635+50	1024 MERIDIAN AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	195	72	36 to 39	-
1636+00	1020 MERIDIAN AVE, SOUTH PASADENA CA	Residential 2-4 Unit	50	0	195	72	36 to 39	-
1637+50	1015 DIAMOND AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	197	72	36 to 39	-
1639+50	1000 EL CENTRO ST, SOUTH PASADENA CA	Residential 5+ Units	50	0	199	72	37 to 40	-
1645+00	808 MERIDIAN AVE, SOUTH PASADENA CA	Residential 2-4 Unit	50	0	198	72	36 to 39	-
1645+50	806 MERIDIAN AVE, SOUTH PASADENA CA	Residential 2-4 Unit	50	5	200	72	36 to 39	-
1647+00	725 HOPE CT, SOUTH PASADENA CA	Residential 1 Unit	50	0	200	72	36 to 39	-
1651+00	1018 MAGNOLIA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	198	72	36 to 39	-
1652+50	1021 GREVELIA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	198	72	36 to 39	-
1653+00	1025 GREVELIA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	198	72	36 to 39	-
1656+50	1039 FOOTHILL ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	189	72	37 to 40	-
1669+50	300 FAIRVIEW AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	196	72	36 to 39	-
1670+00	218 FAIRVIEW AVE, SOUTH PASADENA CA	Residential 1 Unit	50	0	193	72	37 to 40	-
1671+00	1117 COLUMBIA LN, SOUTH PASADENA CA	Residential 1 Unit	50	0	191	72	37 to 40	-
1673+00	1115 COLUMBIA ST, SOUTH PASADENA CA	Residential 1 Unit	50	0	190	72	37 to 40	-
1674+00	209 COLUMBIA ST, PASADENA CA	Residential 1 Unit	50	0	187	72	37 to 40	-
1676+50	1220 PASADENA AVE, PASADENA CA	Residential 1 Unit	50	101	186	72	36 to 39	-
1677+00	1199 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	185	72	37 to 40	-
1678+00	1191 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	183	72	38 to 41	-
1679+00	1175 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	181	72	38 to 41	-
1681+00	1151 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	180	72	38 to 41	-
1681+50	1141 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	179	72	38 to 41	-
1682+00	1131 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	178	72	38 to 41	-
1683+50	202 MADELINE DR, PASADENA CA	Residential 1 Unit	50	0	173	72	39 to 42	-

Civil-Station	Receiver Location	Receiver Type	Vehicle Speed (mph)	Horizontal Distance To Alignment (ft)	Alignment Depth (ft)	FTA Criteria (VdB)	GBV Range (VdB)	# of Impacts
1685+50	205 MADELINE DR, PASADENA CA	Residential 1 Unit	50	0	165	72	39 to 42	-
1686+00	1059 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	162	72	40 to 43	-
1686+50	1051 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	161	72	40 to 43	-
1687+00	1041 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	160	72	40 to 43	-
1687+50	1031 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	159	72	40 to 43	-
1688+00	216 ARLINGTON DR, PASADENA CA	Residential 1 Unit	50	0	157	72	40 to 43	-
1692+50	953 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	146	72	42 to 45	-
1693+00	949/ 955 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	145	72	42 to 45	-
1693+50	929 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	144	72	42 to 45	-
1694+50	212 WIGMORE DR, PASADENA CA	Residential 1 Unit	50	0	141	72	42 to 45	-
1695+50	215 WIGMORE DR, PASADENA CA	Residential 1 Unit	50	0	139	72	42 to 45	-
1699+00	150 BELLEFONTAINE ST, PASADENA CA MARLINDA IMPERIAL CONVALESCENT HOSPITAL	Hospital	50	180	134	72	40 to 43	-
1701+50	100 CONGRESS ST, PASADENA CA HUNTINGTON HOSPITAL	Hospital	50	179	129	72	40 to 43	-
1704+50	765 S PASADENA AVE, PASADENA CA	Residential 1 Unit	50	0	122	72	45 to 48	-
1705+00	734 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	121	72	45 to 48	-
1707+00	726 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	117	72	45 to 48	-
1707+50	714 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	115	72	45 to 48	-
1708+50	696 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	112	72	46 to 49	-
1709+50	678 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	110	72	46 to 49	-
1710+00	602 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	109	72	46 to 49	-
1711+50	650 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	105	72	47 to 50	-
1712+00	646 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	103	72	47 to 50	-
1712+50	640 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	99	72	48 to 51	-
1713+00	628 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	99	72	48 to 51	-
1713+50	620 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	97	72	48 to 51	-
1714+50	602 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	96	72	48 to 51	-
1715+00	600 S ST JOHN AVE, PASADENA CA	Residential 1 Unit	50	0	96	72	48 to 51	-
1715+50	230 CALIFORNIA ST, PASADENA CA	Residential 1 Unit	50	0	94	72	48 to 51	-
1719+00	225/227/229/231/233 W CALIFORNIA BLVD, PASADENA CA	Residential 5+ Unit	50	0	88	72	53 to 56	-
1719+00	535 S PASADENA AVE, PASADENA CA SEQUOYAH ELEMENTARY SCHOOL	Institutional	50	0	88	75	53 to 56	-
1724+00	275 PALMETTO DR, PASADENA CA	Residential 1 Unit	50	259	132	72	39 to 42	-
1724+00	454 PASADENA AVE, PASADENA CA	Residential 1 Unit	50	190	63	72	48 to 51	-
1724+50	164 BELLEVUE DR, PASADENA CA	Residential 1 Unit	50	191	60	72	49 to 52	-
1725+00	266 BELLEVUE DR, PASADENA CA	Residential 1 Unit	50	239	119	72	40 to 43	-
1725+50	135 BELLEVUE DR, PASADENA CA	Residential 5+ Units	50	372	50	72	45 to 48	-
1726+00	416 GORDON TER, PASADENA CA	Residential 1 Unit	50	237	107	72	41 to 44	-
1727+00	406 GORDON TER, PASADENA CA	Residential 1 Unit	50	219	92	72	44 to 47	-
1728+50	376 GORDON TER, PASADENA CA	Residential 1 Unit	50	233	73	72	45 to 48	-
1729+00	372 PASADENA AVE, PASADENA CA	Residential 1 Unit	50	200	30	72	53 to 56	-

Civil-Station	Receiver Location	Receiver Type	Vehicle Speed (mph)	Horizontal Distance To Alignment (ft)	Alignment Depth (ft)	FTA Criteria (VdB)	GBV Range (VdB)	# of Impacts
1729+00	288 WAVERLY DR, PASADENA CA	Residential 1 Unit	50	239	69	72	46 to 49	-
1730+50	147 WAVERLY DR, PASADENA CA	Residential 1 Unit	50	305	0	72	53 to 56	-
1732+50	273 WAVERLY DR, PASADENA CA	Residential 5+ Units	50	258	1	72	55 to 58	-
1735+50	134 VALLEY ST, PASADENA CA	Residential 5+ Units	50	208	0	72	57 to 60	-
1739+50	169 SAINT JOHN AVE, PASADENA CA MARANATHA HIGH SCHOOL	Institutional	50	238	0	75	56 to 59	-

5.2.2 Groundborne Noise and Vibration Mitigation

No groundborne noise and vibration impacts are projected for the Freeway tunnel alignment hence mitigation measures are not necessary.

6 Tunnel Construction Groundborne Noise and Vibration Impacts

6.1 Groundborne Noise and Vibration Methodology

Construction activities can result in varying degrees of ground vibration, depending on the equipment, the type of construction operation being performed, and the location of equipment inside a construction zone and its distance from the nearest sensitive receptor. Any vibration impacts for construction of the tunnel alignment would occur if at all due to groundborne noise and/or vibration from tunnel boring, supply trains and spoils removal and construction for stations. For the SR710 tunnel alignments, blasting is not anticipated. The proposed LRT tunnel is shallower than the Freeway tunnel and hence the more likely of the two to cause vibration impact if at all. The analysis and discussion is for the LRT tunnel, but also applies to the Freeway tunnel except that the level of impacts associated with construction of the Freeway tunnel will be less due to the greater depth of the latter.

For most of the LRT tunnel alignment, with the tunnel boring machines (TBM), operated at 60 ft or deeper, which cuts the full tunnel diameter in a rotary fashion at speeds in the range of 3 to 5 revolutions per minute, vibration levels are not likely to be perceptible on the surface unless the tunnel is directly under a sensitive receptor. At the South portal there are residences approximately 100 feet away from the tunnel alignment. It is not likely that vibration from the TBM will be perceptible at this distance either. The proposed tunnel boring for the LRT tunnel would be accomplished with two TBMs working simultaneously. For the freeway tunnel the proposed tunnel boring would be accomplished with four TBMs working simultaneously. Typical vibration data for TBMs (e.g., Ref. 11) was used to estimate vibration levels from operation of the TBMs.

Vibration impact from the tunnel construction due to supply trains and trains for spoils removal operated in the bored tunnels is based on typical vibration levels from data reported in Reference 5. If a conveyor is used to remove spoils, there will be no vibration impact from this activity. A conveyor is simply a moving conveyor belt onto which soil and rock are place to be carried along to the point of removal from the tunnel. The belt runs continuously and produces very little vibration compared to a muck train. If muck trains are used in lieu of a conveyor system, groundborne vibration and noise levels will be similar to those generated by the material supply train.

Construction activities at other construction sites or during excavation of stations are not likely to result in vibration impact unless there are sensitive receptors within 200 feet of the construction activity. The proximity of sensitive receptors near the following station sites are as follows:

- Fillmore: 202+50 to 206+50 – No receptors within 200 ft
- South Pasadena: 236+50 to 240+50 – approximately 20 residential receptors within 200 ft
- Huntington: 294+00 to 298+00 – approximately 5 residential receptors within 200 ft
- Alhambra: 319+50 to 324+00 – approximately 2 residential receptors within 200 ft

The FTA provides criteria for short-term impacts (e.g., annoyance related) during construction, with the criteria equivalent to the criteria provided for operational groundborne vibration and noise discussed in Section 3.2 above taking into account the frequency of event per day.

6.2 Groundborne Noise and Vibration Impacts

The evaluation of impact due to TBM operation indicates that vibration levels possibly as high as 0.01 inch/second, peak particle velocity (PPV) may occur when the TBM is directly below the receptor. An equivalent annoyance level would be 77 VdB. The TBM is projected to advance at 22 feet/day, which means that this level of vibration would last probably no more than 2 or 3 days. The Category 2 (residential) vibration criterion for

Infrequent Events is 80 VdB and for Occasional Events is 75 VdB. Consequently there may be a very short term vibration impact due to TBM operation, when the tunnel is being constructed directly below a sensitive receiver. This level of vibration would not be capable of producing damage to residences.

Supply trains and muck trains (if used instead of conveyors) would produce greater vibration and groundborne noise than produced by LRT operations due primarily to the type of track construction used for tracked vehicles (trains) servicing construction activity in the tunnel. Even though supply train speeds are generally much slower (e.g., 15 mph compared to 45 mph), the jointed-rail used in service track used during construction can sometimes result in from 5 to 8 dB higher noise and vibration levels compared with the levels associated with LRT operations.

The frequency of supply trains per day is typically one or two, which means that the events are very infrequent. The groundborne noise criterion for Category 2 (residential) receivers is 43 dBA for infrequent events. In some areas of the alignment, this level could be exceeded by as much as 10 dBA. This FTA criterion was determined to protect persons at night when they are sleeping. Consequently, if supply train groundborne noise were determined to be an issue, a possible mitigation measure would be to run the trains only during daytime hours, in which there might still be an occasional temporary impact. A mitigation measure that could be employed at the track level to reduce groundborne noise is an under-track mat (commonly referred to as a ballast mat), which has been used successfully to reduce vibration for supply and muck trains in the past. Ballast mats are elastomeric sheets that can be placed under the muck train tracks to reduce vibration. These mats are typically 1 inch or more thick. Construction of previous LA Metro tunnel projects has shown ballast mats to be effective at significantly reducing groundborne noise impacts.

Muck trains generally run much more frequently than supply trains, the frequency depending on the amount of soil being generated and the distance to the haul out location. The Category 2 criterion for occasional events is 40 dBA. Consequently, groundborne noise from muck trains could be 13 dBA above the criterion.

Pile driving and other vibration producing activity at station sites may impact residential receptors within 200 feet of the construction activity. Best management practices and vibration monitoring to limit vibration at these receptors can be employed to minimize if not eliminate vibration impacts. Where vibration impacts cannot be avoided there may be short-term construction impacts around the stations sites.

6.2.1 Sensitive Receptor of Concern

A Grifols Biologicals, Inc. (Biomat) laboratory located at 2410 Lillyvale Avenue in Los Angeles is being considered as a sensitive receptor. The concern is dust being stirred up (becoming airborne) inside their cleanroom laboratories by vibration created during tunnel boring. This division of Grifols specializes in the development and manufacturing of high-quality, plasma-derived protein therapies for the medical industry. The closest labs at this Grifols facility are located at least 450 feet and most likely 600 feet from where the closest tunnel would be bored.

At a distance of 450 feet, a conservative estimate of the ground vibration during tunnel boring is approximately 0.0018 inches/second (RMS). This is equivalent to a vibration level of 65 VdB. There is no published industry criterion available to evaluate the vibration level necessary for dust inside a cleanroom to become airborne. For a dust particle to become airborne the vibration would need to accelerate the particle enough to overcome adhesion factors such as van der Waals forces, which act at the molecular level and involve electrostatic interactions.

A level of 66 VdB (0.002 inches/second) although very conservative is sometimes used as an unofficial criterion in the micro-electronics industry as a threshold to evaluate the potential for generation of airborne dust due to vibration. The reason for this is that micro-electronics' cleanrooms are designed to a vibration level that is substantially less than this. More recently higher levels are being evaluated as possible criteria for limiting vibration as it relates to dust in cleanrooms.

It would appear that based on this preliminary analysis there would be no impact from tunnel boring vibration. Vibration-sensitive manufacturing or research of the type that Grifols engages in will require a more detailed evaluation to define the acceptable vibration level to avoid causing dust in their cleanrooms to become airborne.

During the engineering phase of the project this issue should be examined in more detail based on information to be provided by Grifols about ambient levels of dust in their laboratory and refinement of vibration predictions based on identification of the tunnel boring machine and specific soil conditions between the tunnel alignment and the Grifols laboratory. Additional coordination with Grifols regarding any mitigation measures if needed for vibration will be developed further during final design if a tunnel alternative is selected as the preferred alternative.

6.3 Groundborne Noise and Vibration Mitigation

Construction activities should be carried out in compliance with FTA criteria and guidelines, and any applicable local regulations. In addition, specific property line vibration limits should be developed during final design and included in the construction vibration specifications for the project, and regular vibration monitoring should be performed during construction to verify compliance with these limits. This approach allows the contractor flexibility to meet the vibration limits in the most efficient and cost-effective manner.

Following are vibration control measures that may be applied as needed to meet the vibration limits:

- Use pre-drilled holes for soldier piles
- Where feasible use soil mix wall for excavation
- A comprehensive construction vibration specification should be incorporated into all construction bid documents. The existence and importance of vibration control specifications should be emphasized at pre-bid and pre-construction conferences, if necessary.
- Require contractor to assess potential for damage to buildings within 200 feet of areas where excavation requires use of driven piles either by impact or vibratory methods.
- Require contractor to assess potential for damage to buildings within 100 feet of tunnel boring.
- If there is a determination that damage might occur require contractor to perform a physical survey of buildings to document existing damage.
- Require contractor to initially conduct vibration monitoring daily at the nearest representative affected buildings during the startup of tunnel boring. Vibration measurements should be measured in the vertical direction on ground surface and measured during peak vibration generating construction activities. If the measured vibration data is in compliance with the vibration limits, either in terms of velocity levels in dB re: 1 micro-inch/second or peak particle velocity in inches/second, then vibration monitoring may be performed weekly instead of daily monitoring.
- Require the contractor to perform vertical direction vibration root mean square (rms) monitoring on the ground at the nearest representative residential structure during supply train operations in the tunnels. These measurements should be repeated at approximately one-mile intervals along the tunnel construction.
- A public notification program should be implemented to alert residents well in advance of particular disruptive construction activities.
- A complaint resolution procedure should also be put in place to rapidly address any noise and vibration problems that may develop during construction.

With incorporation of construction noise and vibration mitigation measures and best management practices, presented above, and development of comprehensive construction noise and vibration specifications, construction noise and vibration impacts can be minimized to an acceptable level.

If complaints occur after the supply train is operational, a possible vibration mitigation measure would be to reduce train speeds in the vicinity of noise-sensitive receptors. Given the abundance and distribution of sensitive receptors along the alignments this may not be possible. Other potential mitigation measure could consist of use of ballast mats underneath the train rails. A conveyor system to remove spoils would eliminate groundborne noise and vibration impacts.

The following mitigation measures are implemented in the contract documents:

Tunnel Boring Machine:

- Maintenance and Operation: maintain machinery in good working order.

Supply and Muck Trains:

- Resilient Mat: A resilient system to support the tunnel train tracks would reduce the groundborne noise at least 4 dBA.
- Speed: Limiting the speed of the tunnel train where feasible in the vicinity of residences would reduce the groundborne noise.

7 Terminology

7.1 Acoustical Terms

- Ambient noise: The all-encompassing noise associated with a given environment at a specified time, being usually a composite of sound from many sources at many directions, near and far; no particular sound is dominant.
- A-weighted noise level in decibels (dBA): The overall noise level obtained by use of A-weighting which simulates the manner in which the human ear hears sound.
- Cycles per second: A unit of frequency, same as hertz (Hz).
- Decibel (dB): A unit of level which denotes the ratio between two quantities that are proportional to power; the number of decibels is 10 times the logarithm (to the base 10) of this ratio. For sound, the reference sound pressure is 20 micro-Pascals.
- Octave and octave band: Octave is the frequency interval between two sounds whose frequency ratio is 2. It is convenient to represent the frequency spectrum of a sound using octave bands over a broad range of frequencies.
- Overall noise level: Noise is comprised of sounds having various frequencies. The energy of all of these sounds is referred to as the overall level and is measured in dBA.
- Octave band noise level: The sound energy contained in one octave frequency band is the measured level in decibels (dB).

8 References

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9. Memorandum to Sound Transit by Wilson, Ihrig & Associates, regarding Long Range Propagation Tests at UW, dated 3 April 2008.
10. Silicon Valley Rapid Transit Project, Line Segment Vibration Design Report, Rev. 0, report prepared by HNTB/Wilson Ihrig & Associates for Valley Transportation Authority, October 2005.
11. Dowding, C.H., Construction Vibration, 2000.

9 Appendix A: LSR Data

Table 9-1 Borehole Z1B8 Line Source Response Coefficients

Frequency (Hz)	**A**	**B**	**C**	**D**
3.15	-3.02	-14.00	-0.0040	0.0218
4	16.78	-23.32	-0.0047	0.0330
5	29.18	-26.59	-0.0438	0.0411
6.3	35.76	-27.71	-0.0431	0.0233
8	32.09	-21.86	-0.0834	-0.0011
10	35.62	-23.17	-0.0811	-0.0071
12.5	51.48	-34.21	-0.0317	0.0323
16	12.87	-9.97	-0.1232	0.0107
20	35.84	-22.58	-0.1172	0.0605
25	43.08	-25.32	-0.0916	0.0421
31.5	90.11	-53.48	0.0074	0.0770
40	78.22	-44.44	-0.0107	0.0430
50	100.37	-59.00	0.0459	0.0809
63	104.09	-62.33	0.0690	0.0710
80	65.59	-41.83	0.0339	0.0194
100	108.08	-71.07	0.1505	0.0620
125	89.90	-63.25	0.1378	0.0493
160	72.41	-53.66	0.1090	0.0604

$$LSR = A + B \cdot \log(S) + C \cdot Z + D \cdot X$$

Figure 9-1 Borehole Z1B8 Line Source Response at 50 ft Depth

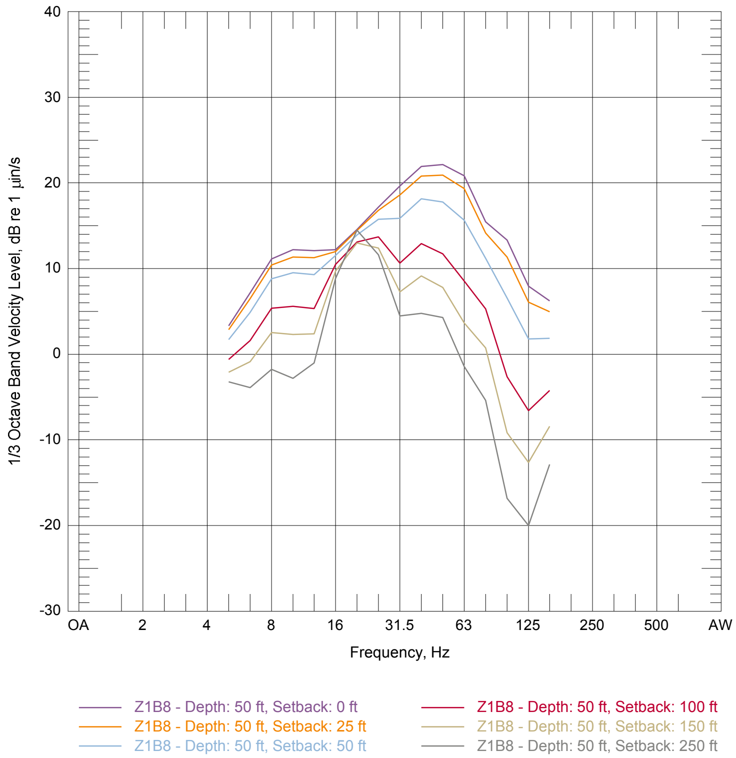

Figure 9-2 Borehole Z1B8 Line Source Response at 140 ft Depth

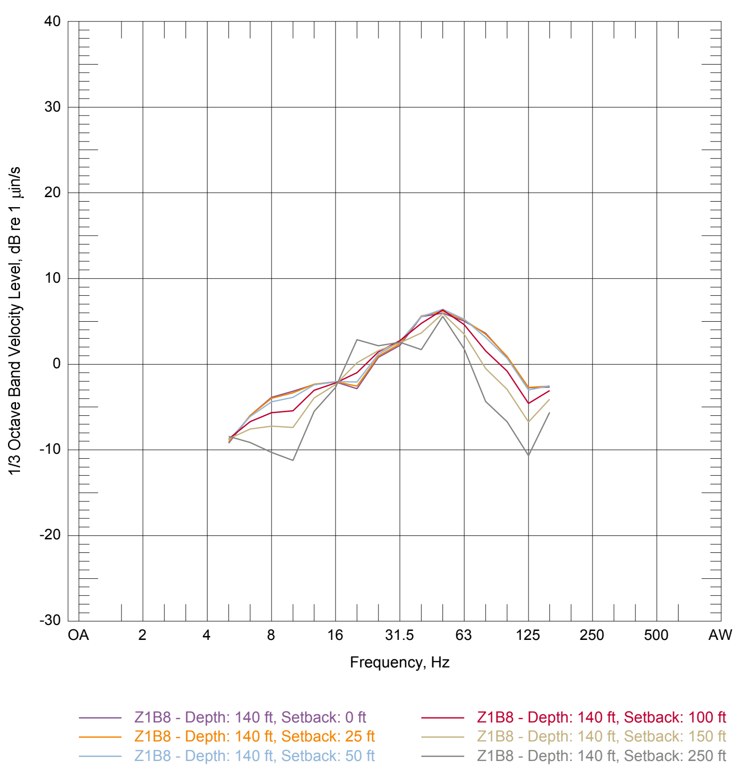

Table 9-2 Borehole Z2B5 Line Source Response Coefficients

Frequency (Hz)	**A**	**B**	**C**	**D**
3.15	-24.10	2.35	-0.0746	-0.0485
4	-4.50	-4.80	-0.1326	-0.0438
5	5.47	-12.37	-0.0889	0.0005
6.3	30.92	-25.20	-0.0828	0.0318
8	44.44	-31.09	-0.0720	0.0393
10	81.15	-52.13	-0.0006	0.0887
12.5	59.09	-37.47	-0.0254	0.0539
16	47.66	-29.03	-0.0598	0.0298
20	37.74	-24.23	-0.0347	0.0185
25	11.34	-8.47	-0.0609	-0.0472
31.5	50.23	-29.39	-0.0137	-0.0538
40	67.84	-39.03	0.0273	-0.0664
50	42.53	-21.42	-0.0455	-0.1179
63	63.45	-31.29	-0.0698	-0.1052
80	105.38	-58.54	0.0102	-0.0349
100	155.17	-91.68	0.1092	0.0490
125	172.65	-104.74	0.1794	0.0816
160	135.35	-83.64	0.1500	0.0354

$$LSR = A + B \cdot \log(S) + C \cdot Z + D \cdot X$$

Figure 9-3 Borehole Z2B5 Line Source Response at 50 ft Depth

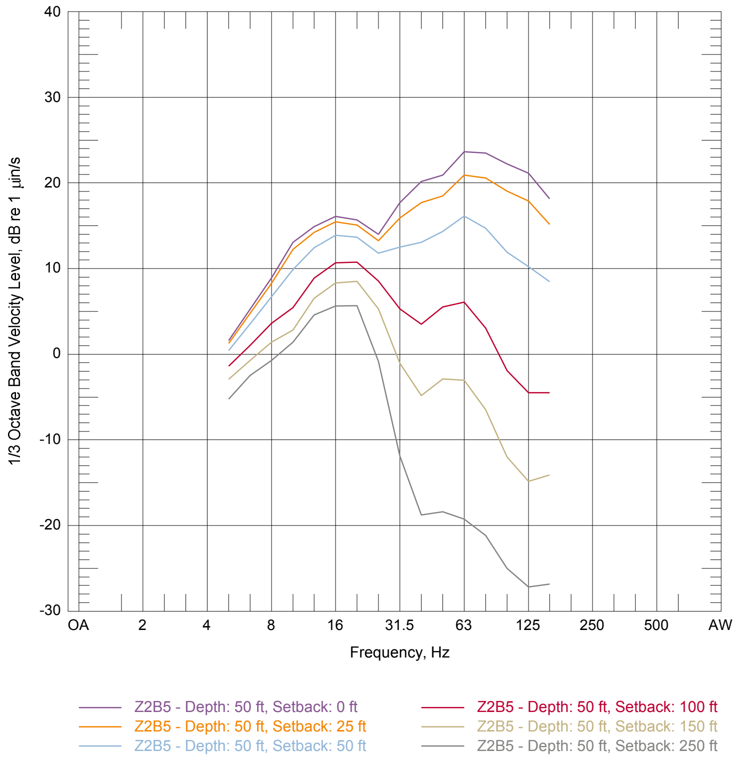

Figure 9-4 Borehole Z2B5 Line Source Response at 140 ft Depth

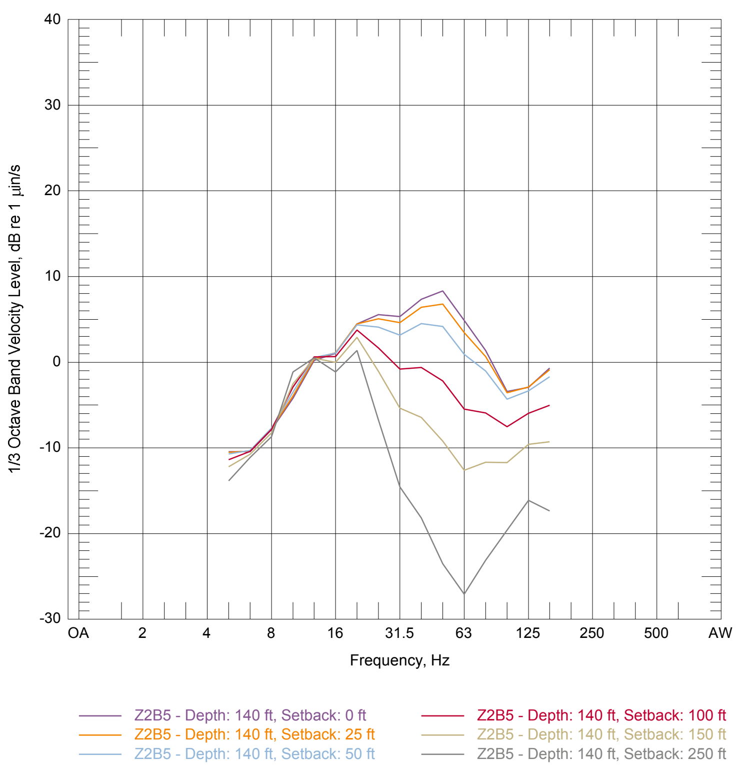

Table 9-3 Borehole Z3B2 Line Source Response Coefficients

Frequency (Hz)	**A**	**B**	**C**	**D**
3.15	13.26	-22.53	-0.0490	0.0117
4	-3.02	-8.06	-0.1202	-0.0417
5	4.68	-10.85	-0.1208	-0.0039
6.3	-4.56	-0.74	-0.1685	-0.0543
8	-6.76	2.36	-0.1965	-0.0501
10	20.00	-11.53	-0.1513	-0.0232
12.5	46.68	-27.58	-0.0872	0.0098
16	71.06	-44.34	-0.0096	0.0728
20	98.47	-61.87	0.0454	0.1249
25	96.91	-59.28	0.0283	0.1193
31.5	34.83	-18.08	-0.1128	0.0091
40	58.59	-30.33	-0.0929	0.0208
50	28.25	-9.83	-0.1785	-0.0434
63	35.18	-17.17	-0.1219	-0.0238
80	65.43	-31.05	-0.1201	-0.0180
100	77.80	-38.13	-0.1048	0.0081
125	59.99	-26.47	-0.1575	-0.0061
160	103.78	-56.40	-0.0195	0.0889

$$LSR = A + B \cdot \log(S) + C \cdot Z + D \cdot X$$

Figure 9-5 Borehole Z3B2 Line Source Response at 50 ft Depth

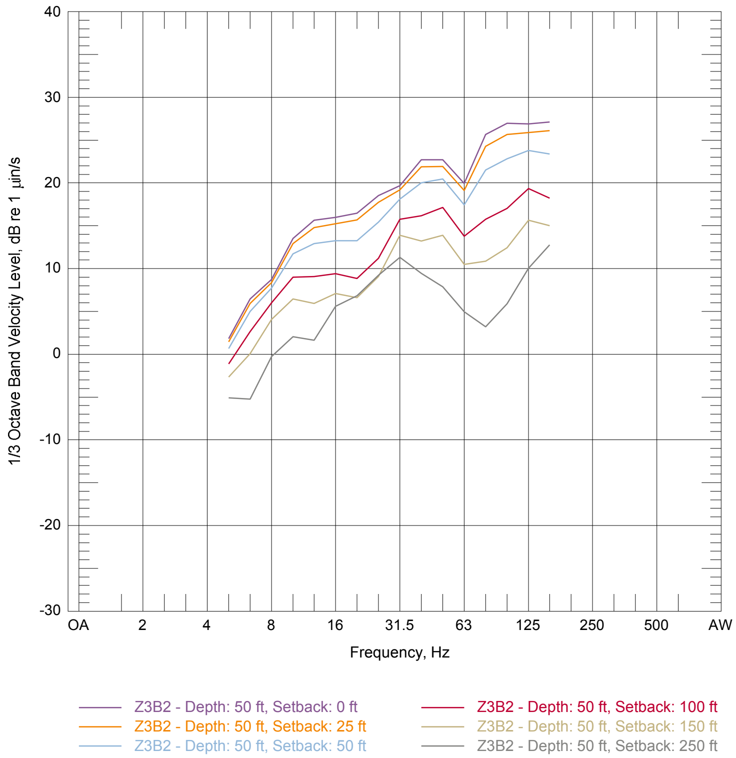

Figure 9-6 Borehole Z3B2 Line Source Response at 140 ft Depth

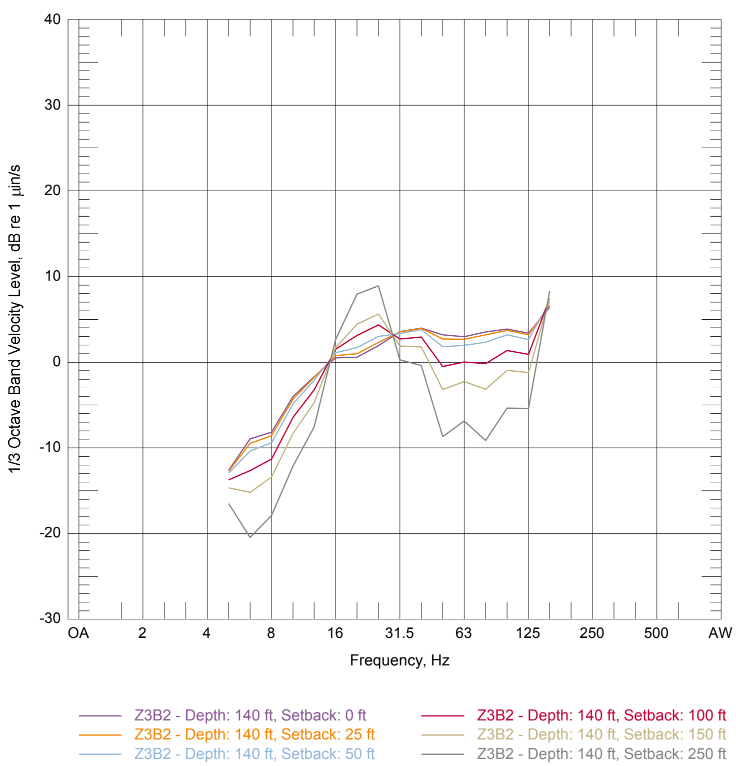

Table 9-4 Borehole Z3B3 Line Source Response Coefficients

Frequency (Hz)	**A**	**B**	**C**	**D**
3.15	29.42	-28.47	-0.0032	-0.0027
4	22.89	-23.72	-0.0178	-0.0235
5	-4.73	-5.42	-0.1068	-0.0365
6.3	-34.96	14.61	-0.1875	-0.0778
8	27.12	-21.52	-0.0765	-0.0017
10	4.00	-6.81	-0.1126	-0.0175
12.5	32.06	-22.21	-0.0502	0.0016
16	56.38	-36.45	-0.0096	0.0409
20	35.24	-24.58	-0.0106	0.0077
25	6.83	-7.29	-0.0388	-0.0422
31.5	21.73	-16.83	-0.0242	0.0077
40	88.82	-53.21	0.0600	0.0622
50	96.47	-58.06	0.0767	0.0756
63	77.01	-50.42	0.0962	0.0673
80	112.45	-68.67	0.1006	0.0804
100	86.95	-49.89	0.0329	-0.0109
125	91.81	-53.87	0.0492	0.0006
160	68.45	-40.20	0.0005	-0.0125

$$LSR = A + B \cdot \log(S) + C \cdot Z + D \cdot X$$

Figure 9-7 Borehole Z3B3 Line Source Response at 50 ft Depth

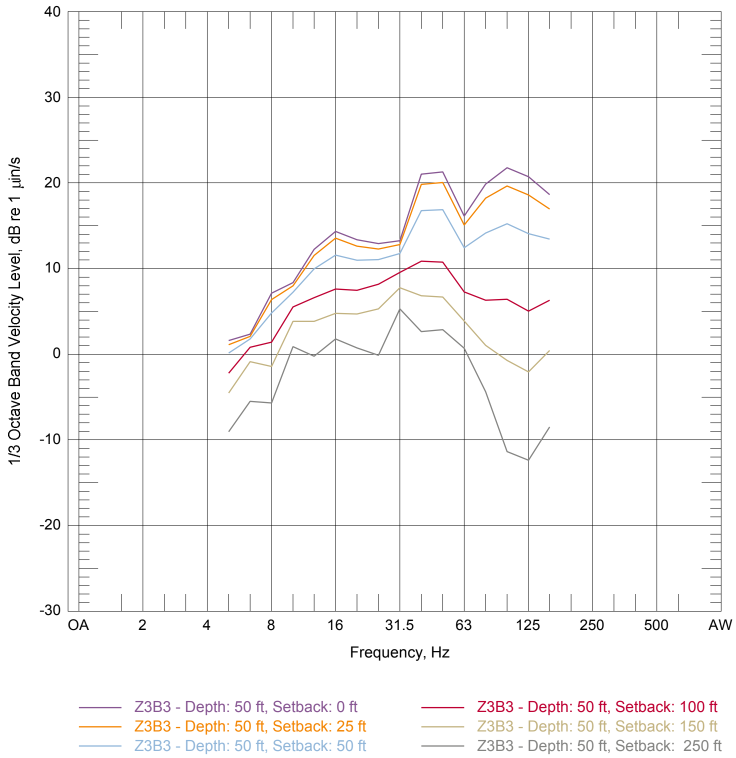

Figure 9-8 Borehole Z3B3 Line Source Response at 140 ft Depth

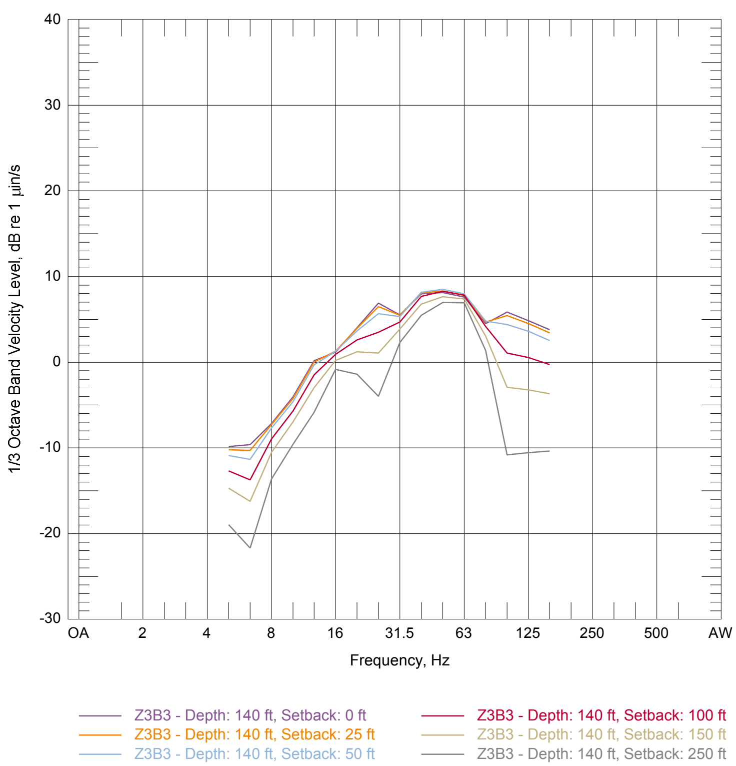

Table 9-5 Borehole Z3B8 Line Source Response Coefficients

Frequency (Hz)	**A**	**B**	**C**	**D**
3.15	27.80	-21.34	-0.0797	-0.0805
4	66.12	-49.35	0.0919	-0.0006
5	59.86	-45.42	0.0772	-0.0157
6.3	37.32	-29.55	-0.0064	-0.0323
8	40.36	-28.01	-0.0222	-0.0375
10	44.15	-24.42	-0.1026	-0.0846
12.5	64.72	-36.87	-0.0558	-0.0407
16	75.05	-41.68	-0.0383	-0.0070
20	66.75	-35.29	-0.0745	-0.0297
25	113.98	-65.24	0.0101	0.0552
31.5	81.20	-41.19	-0.0730	-0.0329
40	24.04	-7.49	-0.1182	-0.1241
50	17.37	-4.15	-0.0969	-0.1748
63	49.44	-27.86	-0.0159	-0.0588
80	31.68	-14.06	-0.2056	-0.0945
100	26.57	-16.86	-0.1394	-0.0765
125	56.70	-38.65	-0.0246	-0.0307
160	40.41	-31.13	0.0171	-0.0276

$$LSR = A + B \cdot \log(S) + C \cdot Z + D \cdot X$$

Figure 9-9 Borehole Z3B8 Line Source Response at 43 ft Depth

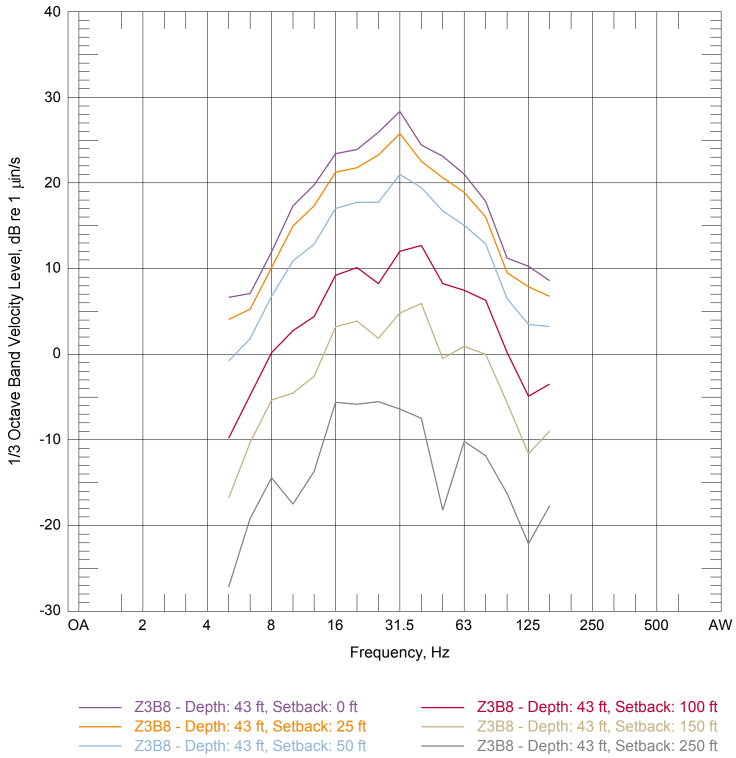

Figure 9-10 Borehole Z3B8 Line Source Response at 85 ft Depth

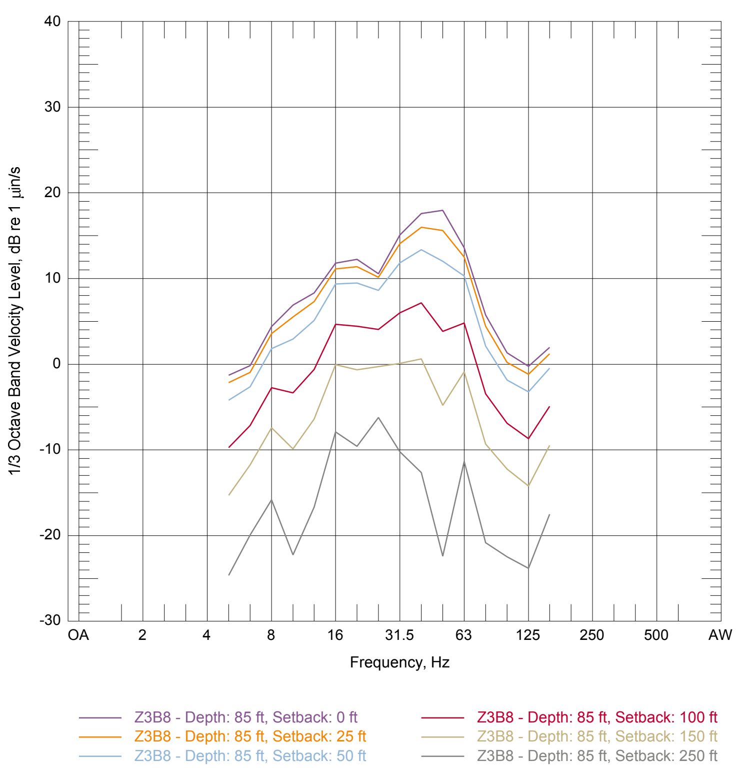

Table 9-6 Borehole Z3B12 Line Source Response Coefficients

Frequency (Hz)	A	B	C	D
3.15	55.04	-33.11	-0.1402	0.0019
4	69.64	-43.35	-0.1044	0.0407
5	76.85	-49.47	-0.0486	0.0477
6.3	60.09	-39.51	-0.0622	0.0243
8	48.46	-32.40	-0.0578	0.0228
10	42.87	-27.68	-0.0506	-0.0004
12.5	63.66	-40.01	0.0194	0.0158
16	77.29	-47.02	0.0201	0.0475
20	66.30	-40.67	0.0069	0.0494
25	39.21	-23.80	-0.0588	0.0180
31.5	42.91	-22.78	-0.1112	0.0184
40	112.19	-59.99	-0.0676	0.0985
50	118.76	-58.01	-0.1438	0.0742
63	123.96	-61.27	-0.1117	0.0381
80	80.81	-36.90	-0.1650	-0.0232
100	93.84	-48.31	-0.0700	-0.0263
125	107.37	-57.98	-0.0296	-0.0229
160	74.40	-41.66	-0.0419	-0.0218

$$LSR = A + B \cdot \log(S) + C \cdot Z + D \cdot X$$

Figure 9-11 Borehole Z3B12 Line Source Response at 50 ft Depth

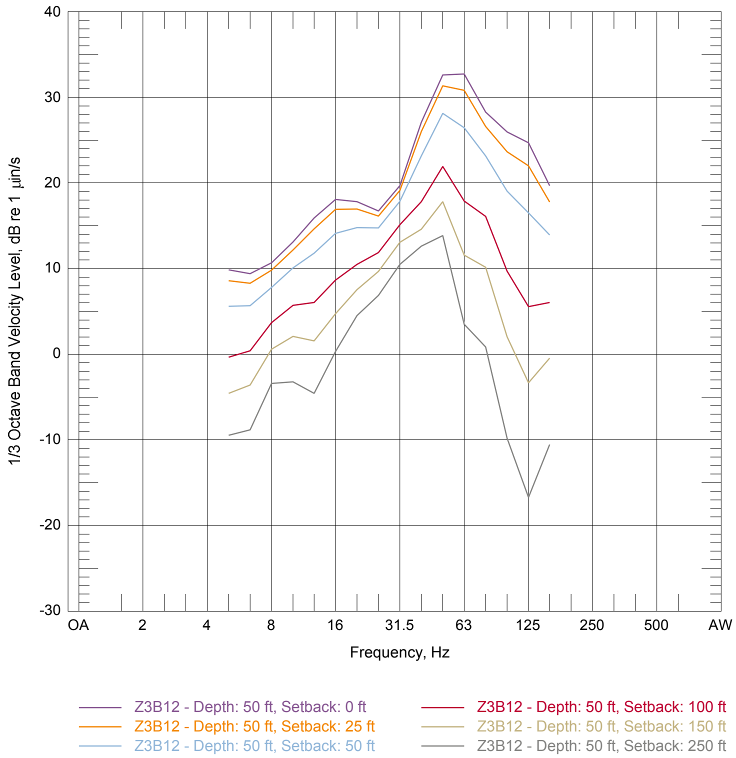

Figure 9-12 Borehole Z3B12 Line Source Response at 140 ft Depth

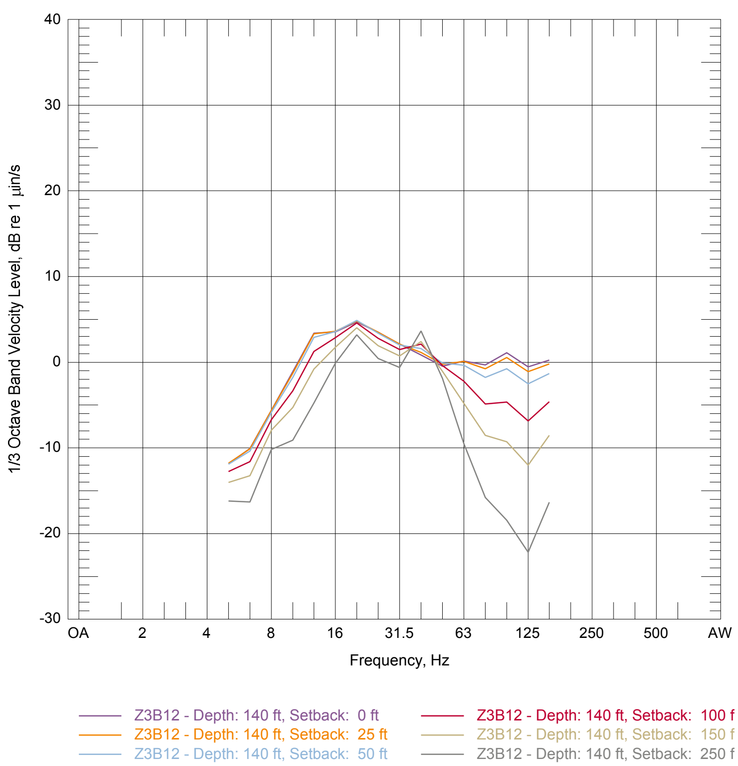

Table 9-7 Borehole Z4B4 Line Source Response Coefficients

Frequency (Hz)	**A**	**B**	**C**	**D**
3.15	48.80	-41.92	0.0811	0.0639
4	19.51	-22.93	0.0280	0.0123
5	1.51	-9.98	-0.0479	-0.0013
6.3	-0.81	-9.04	-0.0447	-0.0009
8	46.26	-35.90	0.0332	0.0517
10	45.88	-32.53	0.0177	0.0257
12.5	27.25	-20.52	0.0262	-0.0090
16	52.10	-34.99	0.0261	0.0390
20	67.44	-41.67	0.0047	0.0322
25	75.61	-47.37	0.0537	0.0441
31.5	68.73	-42.12	0.0059	0.0425
40	36.65	-20.13	-0.0790	-0.0165
50	70.97	-40.63	-0.0316	0.0310
63	94.13	-57.92	0.0913	0.0715
80	69.26	-43.20	0.0218	0.0112
100	69.40	-42.56	-0.0059	-0.0142
125	98.51	-61.19	0.0411	0.0254
160	69.45	-43.95	0.0013	0.0210

$$LSR = A + B \cdot \log(S) + C \cdot Z + D \cdot X$$

Figure 9-13 Borehole Z4B4 Line Source Response at 50 ft Depth

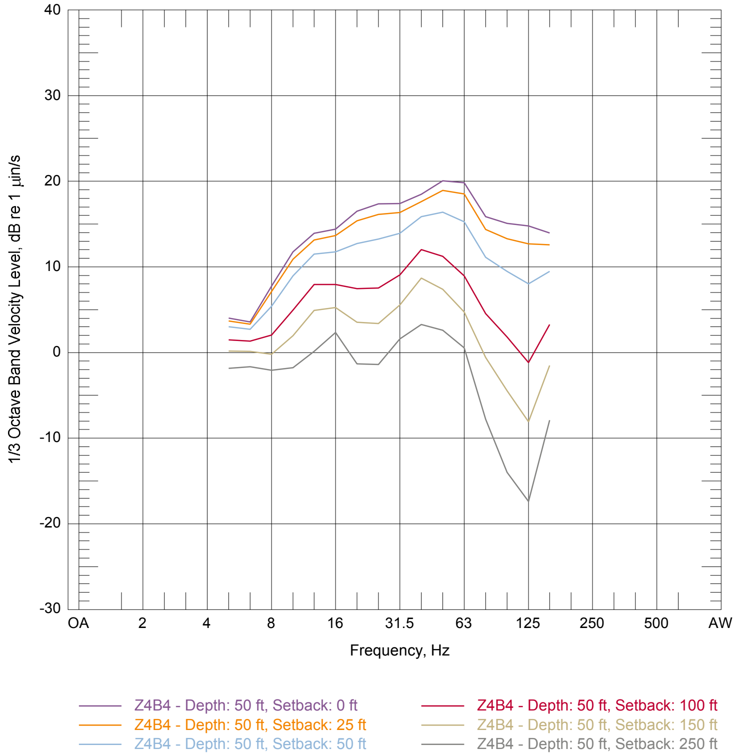

Figure 9-14 Borehole Z4B4 Line Source Response at 140 ft Depth